N3172B.AR.002848
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Final

In-Situ Remediation Pilot Studies (AOC E and AOC I Sites) Sampling and Analysis Plan

Former Naval Ammunition Support Detachment Vieques, Puerto Rico

Prepared for

Department of the Navy

NAVFAC ATLANTIC

Contract No. N62470-02-D-3052
CTO-007

February 2010

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Acronyms and Abbreviations

AOC	Area of Concern
AST	aboveground storage tank
ASTM	American Society for Standards and Materials
bgs	below ground surface
BSSA	benzylsuccinate synthase
BTEX	benzene, toluene, ethylbenzene, xylene
CA	corrective action
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
COC	chain of custody
CSM	Conceptual Site Model
CTO	Contract Task Order
°C	degrees Celsius
DPT	direct push technology
DQE	data quality evaluation
DQI	data quality indicator
DRO	diesel range organics
EBS	Environmental Baseline Survey
EIS	Environmental Information Specialist
EISB	Enhanced In-situ Bioremediation
EQB	Environmental Quality Board
ERA	Ecological Risk Assessment
ERP	Environmental Restoration Program
FID	Flame Ionization Detector
FS	feasibility study
ft	foot/feet
FTL	Field Team Leader
GC	gas chromatograph
GPS	Global Positioning System
GW	Groundwater
HASP	Health and Safety Plan
HHRA	Human Health Risk Assessment
ICP	inductively coupled plasma
IDW	investigation-derived waste
IDWMP	Investigation-derived Waste Management Plan
IS	Internal Standards
ITRC	Interstate Technology & Regulatory Council

LCS	laboratory control sample
LCSD	Laboratory Control Sample Duplicate
LIMS	Laboratory Information Management Systems
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MACTEC	MACTEC Inc.
MCL	maximum contaminant level
MDL	method detection limit
mg/kg	milligrams per kilogram
MOV	Municipality of Vieques
MPE	multiphase extraction
MQAPP	Master Quality Assurance Project Plan
MS	mass spectrometer
MS/MSD	matrix spike/matrix spike duplicate
MTBE	methyl tert butyl ether
N/A	not applicable
Navy	Department of the Navy
NFA	no-further-action
NIRIS	Navy Installation Restoration Information System
ORC	Oxygen Release Compound
OU	operable unit
OVM	organic vapor monitor
PA/SI	Preliminary Assessment/Site Investigation
PAL	project action limit
PAOC	potential area of concern
PDF	portable document format
PID	photoionization detector
PM	Project Manager
POC	Point of Contact
PQO	project quality objective
PREQB	Puerto Rico Environmental Quality Board
PVC	polyvinyl chloride
QA	quality assurance
QAMS	Quality Assurance Management Section
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	quality control
QL	quantitation limit
RAB	Restoration Advisory Board
RI	Remedial Investigation
ROD	record of decision
ROI	radius of influence
RPD	relative percent difference
RPM	Remedial Project Manager
RSD	relative standard deviation

RSL	Regional Screening Level
RT	retention time
SAP	Sampling and Analysis Plan
SB	Subsurface Soil Sample
SSC	Site Safety Coordinator
SSC-HW	Site Safety Coordinator Hazardous Waste
SOP	standard operating procedure
SVOA	semivolatile organic analytes
SVOC	semivolatile organic compounds
SW	surface water
SWO	Safe Work Observation
TCLP	Toxicity Characteristic Leaching Procedure
TBD	to be determined
TOC	Total organic carbon
U.S.	United States
UFP	Uniform Federal Policy
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
UST	underground storage tank
VOA	volatile organic analytes
VOC	volatile organic compound

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Executive Summary

In 2008, Remedial Investigation (RI) Reports were issued for Area of Concern (AOC) E (CH2M HILL, 2008a) and AOC I (CH2M HILL, 2008c), located on the Former Naval Ammunition Support Detachment (NASD) in western Vieques, Puerto Rico (Figure ES-1). Both reports reached similar conclusions – (1) no unacceptable risks exist for potential ecological exposure; (2) no unacceptable risks exist for hypothetical human exposure to soil (hypothetical because there is no current human use or presence at the sites); and (3) unacceptable risks exist for potable use of groundwater (i.e., use as drinking water) by a hypothetical future resident at the sites.

At AOC E, three volatile organic compounds (VOCs) and two semi-volatile organic compounds (SVOCs) were identified as chemicals of concern (COCs) in groundwater because their concentrations were high enough to pose a potential risk should the groundwater at the site be used for drinking water. These five COCs are:

VOCs

- 1,2-dichloroethane (1,2-DCA)
- methyl tert butyl ether (MTBE)
- xylenes

SVOCs

- 2-methylnaphthalene
- naphthalene

In addition to the above, the RI Report noted that soil contamination, although not posing an unacceptable risk to human or ecological receptors from direct exposure, may represent a continuing source for leaching of COCs to groundwater.

At AOC I, the following three VOCs and three SVOCs were identified in the RI Report as COCs in groundwater:

VOCs

- benzene
- 1,2-DCA
- 1,2-dichloropropane

SVOCs

- bis(2-ethylhexyl)phthalate
- 2-methylnaphthalene
- naphthalene

Both RI Reports recommended that additional samples be collected to support a feasibility study (FS) or pilot study to address the COCs. To ensure the appropriate data were collected to determine which option (i.e., FS versus pilot study) was more appropriate, the following post-RI data were collected in 2008:

- Current groundwater COC concentrations to help evaluate concentration trends over time because more than 2 years had elapsed since groundwater was last sampled
- Geochemical and biological (microbes) groundwater conditions to help evaluate natural attenuation processes
- Soil chemical and physical conditions to help evaluate leaching potential (at AOC E)

Upon evaluation of the post-RI data collected in 2008 as well as historical data, a general decline in groundwater COC concentrations over time was observed. Tables ES-1 and ES-2 demonstrate this for three representative wells at AOC E and AOC I, respectively. Using the groundwater COC concentrations measured over time, as well as site-specific geochemical and microbial information, natural attenuation evaluation and modeling were performed to estimate the time required for natural attenuation processes to degrade the COC concentrations in groundwater to acceptable levels (e.g., Federal Maximum Contaminant Levels [MCLs]). The evaluation indicated that although already low, certain COC concentrations could require more than a decade to decline to acceptable levels. In addition, evaluation of the soil data collected at AOC E suggested residual concentrations of naphthalene may pose a leaching-to-groundwater concern.

Based on consideration of the post-RI and historical data, it was concluded a pilot study is a more appropriate next step at AOCs E and I than preparation of FSs. The rationale for moving forward with a pilot study at each site is:

- Current groundwater COC concentrations are relatively low (with respect to potential cleanup levels such as MCLs), and while there are remedial technologies that are potentially able to reduce high concentrations of contaminants to lower concentrations, few technologies can reduce already low concentrations (such as those observed at AOCs E and I) to even lower concentrations.
- The measured subsurface conditions at AOCs E and I are generally anaerobic, but the types of COCs present degrade preferentially under aerobic conditions.

If an FS was now conducted for each site (instead of a pilot study), the conclusions drawn with respect to the applicability of remedial alternatives would likely have a relatively high level of uncertainty because of the aforementioned site conditions. By proceeding instead with a pilot study, the uncertainties, especially regarding the chosen pilot study technologies (which were chosen because they are the ones most likely to be effective), can be reduced before a final remedy for each site is selected.

There are additional benefits to proceeding with a groundwater pilot study at AOC E and AOC I:

- Concurrent with the groundwater pilot study, a pilot study of the potential to mitigate the soil contaminant leaching concern at AOC E can be performed.
- The area of contamination is relatively small at each site (i.e., several hundred square feet); therefore, the pilot study area can be tailored to cover the entire area of contamination and still remain cost-effective.
- A remedy (albeit in a pilot study phase) is implemented sooner (versus immediately proceeding with the FS-Proposed Plan-Record of Decision process), which is beneficial because the Navy and Municipality of Vieques (MOV) would likely benefit from being able

to return the site unencumbered (i.e., without restrictions) to the MOV in a shorter timeframe.
  - The Navy no longer owns nor is present at AOC E or AOC I and therefore institutional controls will be required as the contaminant concentrations attenuate to acceptable levels. If the pilot study demonstrates the technologies can accelerate achieving cleanup goals, institutional controls duration would likely be reduced.

Based on the above information, the objectives of the pilot studies at AOC E and AOC I are to:

1. Determine if the groundwater pilot study technologies can reduce the groundwater COC concentrations to acceptable levels.
2. Determine if the pilot study technologies can reduce the groundwater cleanup timeframe (relative to natural attenuation).
3. Determine if the soil pilot study technology can reduce the groundwater COCs in soil (primarily naphthalene) at AOC E to levels that do not pose a soil-to-leaching concern.

To achieve objectives 1 and 2 above, a two-phase in-situ remedial process will be pilot tested as follows:

- Implementation of an in-situ chemical oxidation (ISCO) technology. This will involve injecting (either via gravity or low-pressure) a sodium persulfate solution (alkaline activated with sodium hydroxide) into existing wells at AOC E and AOC I. This step will oxidize the COCs and adjust the aquifer to aerobic conditions.
- Following an ISCO incubation period, oxygen releasing compound (ORC) "socks" will be installed in the wells to sustain the oxidizing conditions in the aquifer that are beneficial for COC degradation.

To achieve objective 3 above, an in-situ soil treatment technology will be pilot tested as follows:

- Injecting (either via gravity or direct-push technology [DPT]) a calcium nitrate solution into the unsaturated zone to reduce the mass of COCs in soil, primarily naphthalene, through enhanced anoxic biodegradation.

Concomitant with the above activities, periodic soil and groundwater monitoring (geochemical, chemical, and microbial, as applicable) will be occurring to help evaluate the effectiveness of the pilot study technologies. Upon completion of the pilot testing activities (approximately 2 years), the data will be evaluated in order to determine an appropriate path forward at each site. Depending on the specific outcome at each site, the potential recommendations will be:

- No further action warranted because groundwater concentrations (and soil concentrations at AOC E) have been reduced to acceptable levels throughout the area of contamination. Proceed to a no further action Proposed Plan and Record of Decision.
  - or –
- Proceed to an FS using the information gathered during the pilot study.
  - or –
- Implement additional investigation or pilot study if the data collected suggest additional information is necessary or beneficial to making the final remedy determination for the site.

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Resumen Ejecutivo

En el año 2008, se presentaron los Informes de Investigación para la Remediación (RI en ingles) del Área de Preocupación (AOC, por sus siglas en inglés) E (CH2M HILL, 2008a) y AOC I (CH2M HILL, 2008c), localizadas en el Antiguo Destacamento Naval de Apoyo de Municiones (NASD, por sus siglas en inglés) en el oeste de Vieques, Puerto Rico (Figura ES-1). Ambos informes llegaron a conclusiones similares – (1) no existen riesgos inaceptables para una exposición ecológica potencial; (2) no existen riesgos inaceptables para una exposición humana hipotética a suelos (hipotética porque actualmente no hay presencia humana en estos sitios); y (3) si existen riesgos inaceptables si un residente hipotético futuro usa el agua subterránea como agua potable en estos sitios (ejemplo, usarla para beber).

En AOC E, se identificaron en el agua subterránea como sustancias químicas de preocupación (COCs, por sus siglas en inglés) tres compuestos orgánicos volátiles (VOCs, por sus siglas en inglés) y dos compuestos orgánicos semi-volátiles (SVOCs) (COCs) debido a que sus concentraciones eran lo suficientemente altas como para presentar un riesgo potencial si es que el agua subterránea se usa para beber. Estos cinco COCs son:

VOCs

- 1,2-dicloroetano (1,2-DCA)
- metilo ter butilo eter (methyl tert butyl ether (MTBE))
- xileno

SVOCs

- 2-metil-naftaleno
- Naftaleno

Además de lo mencionado arriba, el Informe RI establece que la contaminación de suelos, aún cuando no presenta un riesgo inaceptable para receptores humanos o ecológicos por exposición directa, puede representar una fuente continua de lixiviación de COCs al agua subterránea.

En AOC I, se identificaron en el Reporte RI los siguientes tres VOCs y tres SVOCs como COCs en el agua subterránea:

VOCs

- benceno
- 1,2-DCA
- 1,2-dicloro-propano

SVOCs

- bis(2-ethylhexyl)phthalate
- 2-metil naftaleno
- naftaleno

Para atender los COCs los dos Reportes RI recomiendan recoger muestras adicionales para apoyar un Estudio de Viabilidad (FS, por sus siglas en inglés) o un estudio piloto. Para asegurarse de que se tomaron los datos adecuados para determinar cual opción (por ejemplo, datos FS versus datos para estudio piloto) era la más apropiada, en el 2008 se tomaron los siguientes datos posteriormente al RI:

- Concentraciones de COC en el agua subterránea actual para ayudar a evaluar la tendencia de las concentraciones a través del tiempo, ya que han pasado más de dos años desde el último análisis de agua subterránea.
- Condiciones geoquímicas y biológicas (microbios) en el agua subterránea para ayudar a evaluar los procesos de atenuación natural.
- Condiciones físicas y químicas del suelo para ayudar a evaluar el potencial de lixiviación (en AOC E).

Luego de la evaluación subsiguiente de los datos RI recogidos en el 2008, así como de los datos históricos, se observó una reducción general de las concentraciones de COCs en el agua subterránea. Esto se demuestra en las Tablas ES-1 y ES-2 para tres pozos representativos en AOC E y AOC I, respectivamente. Utilizando las concentraciones de COC en el agua subterránea medidas a través del tiempo, así como la información geoquímica y microbiológica de cada sitio específico, se llevaron a cabo evaluaciones y modelaje de atenuación natural para estimar el tiempo necesario para que los procesos de atenuación natural degraden las concentraciones de COC en aguas subterráneas a niveles aceptables (ejemplo, Niveles Máximos Federales de Contaminantes [MCLs]). La evaluación indicó que aunque han disminuido, algunas concentraciones de COC podrían necesitar más de una década para que se reduzcan a niveles aceptables. Además, la evaluación de los datos de suelos recogidos en AOC E sugiere que las concentraciones residuales de naftaleno podrían presentar una preocupación de lixiviación hacia el agua subterránea.

En base a las consideraciones del RI posterior y de los datos históricos, se concluye que el siguiente paso más apropiado para AOCs E e I es un estudio piloto en vez de que se desarrolle un FS. El razonamiento para seguir con un estudio piloto en cada sitio es:

- Las concentraciones actuales de COC son relativamente bajas (comparados con los niveles potenciales de limpieza tales como MCLs), y aun cuando hay tecnologías de remediación que potencialmente pueden reducir las concentraciones de contaminantes altas a más bajas, pocas tecnologías pueden reducir concentraciones ya bajas (como las observadas en los AOCs E e I) a concentraciones aún más bajas.
- Las condiciones que se midieron en los subsuelos de AOCs E y I son generalmente anaeróbicas, pero los tipos de COCs presentes se degradan preferiblemente bajo condiciones aeróbicas.

Si se llevara a cabo un FS para cada sitio ahora (en vez de un estudio piloto), las conclusiones que se obtendrían con respecto a la aplicación de alternativas de remediación probablemente tendrían un nivel de incertidumbre relativamente alto debido a las condiciones del sitio previamente mencionadas. Al proceder con un estudio piloto, la incertidumbre, especialmente en relación a las tecnologías del estudio piloto seleccionado (las cuales fueron escogidas porque son las que posiblemente sean más efectivas), puede reducirse antes de que se seleccione un remedio final para cada sitio.

Existen beneficios adicionales para proceder con un estudio piloto para el agua subterránea en AOC E y AOC I:

- Al mismo tiempo del estudio piloto para el agua subterránea, se puede llevar a cabo un estudio piloto del potencial para mitigar la preocupación de lixiviación del contaminante de los suelos en el AOC E.
- El área de contaminación es relativamente pequeña en cada sitio (ejemplo, varios cientos de pies cuadrados); por lo tanto, el área de estudio piloto puede ser diseñada para cubrir el área contaminada en su totalidad y todavía ser costo efectiva.
- Un remedio (no obstante la fase de estudio piloto) se implementa más rápidamente (en vez de proceder inmediatamente con un proceso FS-Plan Propuesto-Récord de Decisión), lo cual sería beneficioso debido a que la Marina y el Municipio de Vieques (MOV, por sus siglas en inglés) probablemente se beneficiarían de la devolución del sitio sin restricciones al MOV en un periodo de tiempo más corto.
- La Marina ya no es dueña ni está presente en AOC E ni en AOC I y por lo tanto se requerirán controles institucionales según las concentraciones de contaminantes alcancen niveles aceptables. Si el estudio piloto demuestra que las tecnologías pueden acelerar el alcance de las metas de limpieza, probablemente se reduciría la duración de los controles institucionales.

En base a la información arriba, los objetivos de los estudios pilotos en AOC E y AOC I son:

1. Determinar si las tecnologías del estudio piloto del agua subterránea pueden reducir las concentraciones de COC en el agua subterránea a niveles aceptables.

2. Determinar si las tecnologías del estudio piloto pueden reducir el periodo de tiempo de la limpieza del agua subterránea (en relación a la atenuación natural).

3. Determinar si la tecnología del estudio piloto para suelos puede reducir los COC del suelo (principalmente naftaleno) en AOC E a niveles que no representen una preocupación de lixiviación a suelos.

Para alcanzar los objetivos 1 y 2 arriba, se probará un proceso piloto de remediación in-situ de dos fases como sigue:

- Implementación de una tecnología de oxidación química "in-situ" (ISCO, por sus siglas en inglés). Este proceso incluirá la inyección (ya sea por gravedad o por baja presión) de una solución de persulfato de sodio (activada con hidróxido de sodio) en los pozos existentes en AOC E y AOC I. Este paso oxidará los COCs y ajustará el acuífero a condiciones aeróbicas.
- Luego de un periodo de incubación ISCO, instalación en los pozos de "medias" de un compuesto que libera oxígeno (ORC, por sus siglas en inglés) para sostener las condiciones oxidantes en el acuífero que son beneficiosas para la degradación de COC.

Para alcanzar el objetivo 3 arriba, se probará un proceso piloto de tecnología de tratamiento de suelos "in-situ" como sigue:

- Inyección a la zona no saturada (ya sea por gravedad o por tecnología de empuje directo [DPT]) de una solución de nitrato de calcio para reducir la masa de COCs en el suelo, principalmente naftaleno, a través de la biodegradación anóxica mejorada.

En conjunto con las actividades arriba mencionadas, se realizarán monitoreos periódicos de suelos y agua subterránea (geoquímicos, químicos y microbial, si aplica) para ayudar con la evaluación de la efectividad de las tecnologías de los estudios pilotos. Una vez completadas las actividades de las pruebas pilotos (aproximadamente 2 años), los datos serán evaluados para determinar el próximo

paso más adecuado para cada sitio. Dependiendo de los resultados específicos para cada sitio, las recomendaciones potenciales serían:

- No se requiere ninguna acción adicional debido a que las concentraciones del agua subterránea (y las concentraciones de suelo en el AOC E) se han reducido a niveles aceptables a través del área de contaminación. Proceder con un Plan Propuesto y Récord Decisión de ninguna acción adicional.

  – o –

- Proceder con un Plan de Vialidad (FS) utilizando la información obtenida durante el estudio piloto.

  – o –

- Implementar investigaciones adicionales o estudios pilotos si los datos recolectados sugieren que información adicional es necesaria o beneficiosa para determinar la remediación final para el sitio.

TABLE ES-1
COC Concentration Trends - AOC E

Station ID	MW01					MW04						MW05			
Sample ID	2016-SB1-C	2016-MW1	NDAEGW01-R03	VWAE-MW01-08C	VWAE-MW01P-08C	NDA023	GWMW04-R01	FD105-2102	NDAEGW04-R03	WAE-GW04-05D	VWAE-MW04-08C	NDA026	NDAEGW05-R03	NDAEFD01-R03	VWAE-MW05-08C
Sample Date	8/4/98	9/11/98	09/01/04	07/29/08	07/29/08	04/27/00	05/21/02	05/21/02	08/30/04	12/09/05	07/28/08	05/01/00	08/30/04	08/30/04	07/29/08
Chemical Name															
Volatile Organic Compounds (µg/L)															
1,2-Dichloroethane	NA	NA	0.5 U	0.5 U	0.5 U	1 U	4.6	4.9	0.59	NA	0.5 U	32	7.2	6.4	0.5 U
Methyl-tert-butyl ether (MTBE)	NA	NA	260	106	150	NA	NA	NA	234	NA	110	NA	1,180	1,220	560
Xylene, total	0.15 U	15 U	26.2	0.86	0.8	0.9 J	1 U	1 U	2 U	NA	0.5 U	20	1 J	1.8 J	28
Benzene	50 U	17	4.1	3.9	3.8	2	0.72 J	0.7 J	0.21 J	NA	0.5 U	6	0.81 J	1.2 J	16
Semi-volatile Organic Compounds (µg/L)															
2-Methylnaphthalene	NA	NA	12	6.3	4.3	5 U	5.4 U	5.4 U	5.1 U	NA	0.05 J	14	5.1 U	5.2 U	16 J
Naphthalene	NA	NA	9.5	4.8	4.3	5 U	5.4 U	5.4 U	5.1 U	NA	0.093 U	15	5.1 U	5.2 U	35 J

Notes:
NA - Not analyzed
U - Analyte not detected
J - Result may be estimated
Shading Indicates Detection

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TABLE ES-2
COC Concentration Trends - AOC I

Station ID	MW04			MW05			MW07		
Sample ID	NDAIGW04-R01	WAI-GW04-06A	VWAI-MW04-08C	NDAIGW05-R01	VWAI-MW05-08C	VWAI-MW05P-08C	NDAIGW07-R01	WAI-GW07-06A	VWAI-MW07-08C
Sample Date	09/23/04	01/10/06	7/23/2008	09/22/04	7/21/2008	7/21/2008	09/24/04	01/10/06	7/22/2008
Chemical Name									
Volatile Organic Compounds (UG_L)									
1,2-Dichloroethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.6	2.5 U
1,2-Dichloropropane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.33 J	0.5 U	2.5 U
Benzene	33.7	4.6	5	0.66	0.5 U	0.5 U	59.3	28	24
Semi-volatile Organic Compounds (UG_L)									
2-Methylnaphthalene	41.4	3.8 J	0.47	9.5	7.5	5.4	82.1	110	31
Naphthalene	46.2	5.5	1.1	5 U	0.33 J	0.26 J	81.4	96	35 J
bis(2-Ethylhexyl)phthalate	10 U	5 U	5 U	9.6 J	5 U	5 U	10 U	5 U	4.2 J

Notes:

J - Reported value is estimated

U - Analyte not detected

UG_L - MIcrograms per Liter

Shading Indicates Detection

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TABLE ES-3

Soil Baseline Data

Sample ID	VWAE-SB20-1618-08C	VWAE-SB20-2830-08C	VWAE-SB20P-1618-08C	VWAE-SB21-1618-08C	VWAE-SB20-1820-08C	VWAE-SB21-2930-08C
Sample Date	7/18/2008	7/18/2008	7/18/2008	7/16/2008	7/16/2008	7/16/2008
Chemical Name						
Volatile Organic Compounds (µg/Kg)						
1,2-Dichlorobenzene	4.3U	4.5U	4.4U	270U	260U	240J
2-Butanone	8.6U	8.9U	8.8U	110J	130J	520U
Benzene	4.3UJ	4.5U	4.4U	270U	260U	390
Isopropylbenzene	4.3U	4.5U	4.4U	620	840	3000
M,P-Xylene	4.3U	4.5U	4.4U	850	1,300	50,000
Methyl Tert Butyl Ether	4.3 U	1.3 J	4.4 U	270U	260U	260U
Methylcyclohexane	4.3U	4.5U	4.4U	270U	260U	720
O-Xylene	4.3U	4.5U	4.4U	240J	490	22,000
Toluene	4.3U	4.5U	4.4U	270U	260U	6,300
SPLP Volatile Organic Compounds (µg/L)						
1,2-Dichlorobenzene	NA	10U	NA	NA	NA	3J
Carbon Disulfide	NA	2 J	NA	NA	NA	2 J
Chloromethane	NA	1 J	NA	NA	NA	15
Ethylbenzene	NA	10U	NA	NA	NA	27
Isopropylbenzene	NA	10U	NA	NA	NA	5J
Methyl Acetate	NA	10U	NA	NA	NA	2J
Toluene	NA	10U	NA	NA	NA	26
Xylene (Total)	NA	10U	NA	NA	NA	180
Semivolatile Organic Compounds (µg/Kg)						
1,1'-Biphenyl	180U	190U	180U	200U	1,400U	340
2-Methylnaphthalene	19 J	7.4 U	8.7 J	10,000	14,000	6,600
Acenaphthene	7.1U	7.4U	180U	270	320J	160J
Anthracene	7.1U	7.4U	7.1 U	110	85	360
Benzo(a)anthracene	1.3 J	7.4 U	7.1 U	310	260	280
Benzo(a)Pyrene	7.1U	7.4U	7.1 U	82	92	43J
Benzo(b)Fluoranthene	7.1U	7.4U	7.1 U	86	91	82J
Benzo(g,h,i)Perylene	7.1U	7.4U	7.1 U	140	160	72J
Benzo(k)Fluoranthene	7.1U	7.4U	7.1 U	56	72	7.5U
Bis(2-Ethylhexyl)Phthalate	180U	190U	180U	1,600	1,700	1,200
Butyl Benzyl Phthalate	180U	190U	180U	590	900J	420
Chrysene	1.2 J	7.4 U	7.1 U	210	240	140J
Dibenzo(a,h)Anthracene	7.1U	7.4U	7.1 U	17J	15J	7.5U

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TABLE ES-3

Soil Baseline Data

Sample ID	VWAE-SB20-1618-08C	VWAE-SB20-2830-08C	VWAE-SB20P-1618-08C	VWAE-SB21-1618-08C	VWAE-SB20-1820-08C	VWAE-SB21-2930-08C
Sample Date	7/18/2008	7/18/2008	7/18/2008	7/16/2008	7/16/2008	7/16/2008
Chemical Name						
Di-N-Butyl Phthalate	180U	190U	180U	61J	1,400U	190U
Fluoranthene	7.1U	7.4U	7.1 U	200	290J	50
Fluorene	3.4 J	7.4 U	1.7 J	460	650J	320
Ideno(1,2,3-cd)Pyrene	7.1U	7.4U	7.1 U	48	54	7.5U
Naphthalene	14 J	7.4 U	7.1 J	5,500	7,600	3,900
Phenanthrene	7.1U	7.4U	7.1 U	900	1,400	410
Pyrene	2.6 J	7.4 U	1.9 J	810	500J	380
SPLP Semivolatile Organic Compounds (µg/L)						
2-Methylnaphthalene	NA	50U	NA	NA	NA	52
BIS(2-ethylhexyl)phthalate	NA	21 J	NA	NA	NA	38J
Naphthalene	NA	50U	NA	NA	NA	71
Total Metals (mg/kg)						
Aluminum	7,290	30,200	8,500	8,700	5,460	13,100
Arsenic	0.31J	2.2	0.38J	0.42J	1.1U	0.57J
Barium	65.3	356J	78.1	79.6	49.3	126J
Beryllium	0.1J	0.56U	0.12J	0.13J	0.086J	0.55U
Calcium	2,010	10,500	2,300	2,110	1,720	2,290
Chromium	6.7	39.3	9.8	8.8	4.6	10.1
Cobalt	5.1J	29.5J	6	6.1	3.6J	15J
Copper	19.3	68.2	23.2	23.3	13.1	25.5
Iron	14,100	53,400	16,100	16,400	10,600	22,800
Lead	1.3R	1.7	1.9R	6.3R	5.3R	7.7
Magnesium	2,030	19,900	2,460	2,390	1,540	2,080
Manganese	367	1,250J	423	496	278	480J
Nickel	4.2U	23.5	4.3U	4.2U	4.4U	3.6J
Potassium	976J	256J	1,090J	1,210J	660J	596J
Vanadium	43.5	176	48.5	49.9	31.8	76.5
Zinc	20.2	69.1	23.9	24.7	17.4	26.6
SPLP Metals (µG/L)						
Aluminum	NA	31,400	NA	NA	NA	29,000
Antimony	NA	4J	NA	NA	NA	3.5UJ
Barium	NA	209	NA	NA	NA	165
Beryllium	NA	0.29	NA	NA	NA	0.77

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TABLE ES-3

Soil Baseline Data

Sample ID	VWAE-SB20-1618-08C	VWAE-SB20-2830-08C	VWAE-SB20P-1618-08C	VWAE-SB21-1618-08C	VWAE-SB20-1820-08C	VWAE-SB21-2930-08C
Sample Date	7/18/2008	7/18/2008	7/18/2008	7/16/2008	7/16/2008	7/16/2008
Chemical Name						
Calcium	NA	6,740	NA	NA	NA	8,210
Chromium	NA	44.4	NA	NA	NA	23.1
Cobalt	NA	18.3	NA	NA	NA	16.1
Copper	NA	83.3	NA	NA	NA	46.5
Iron	NA	61,400	NA	NA	NA	47,500
Lead	NA	2.2	NA	NA	NA	17.5
Magnesium	NA	11,000	NA	NA	NA	5,920
Manganese	NA	950	NA	NA	NA	379
Nickel	NA	20.6	NA	NA	NA	9.6
Potassium	NA	581J	NA	NA	NA	1,260J
Sodium	NA	13,000	NA	NA	NA	23,900
Vanadium	NA	216	NA	NA	NA	168
Zinc	NA	54.9J	NA	NA	NA	87.1J
Wet Chemistry (pH, mg/kg)						
pH	NA	6.64	NA	NA	NA	7.88
TOC	NA	4,420	NA	NA	NA	11,700
Total Petroleum Hydrocarbons (mg/kg)						
TPH-diesel range	11U	11U	11U	830	1,600	600
TPH-gas range	0.45U	0.45U	0.44U	2.7	1.2	5
TPH-oil range	31	18	23	5,100	5,700	3,200
SPLP Total Petroleum Hydrocarbons (mg/L)						
TPH-diesel range	NA	2.5U	NA	NA	NA	0.97J
TPH-gas range	NA	0.5U	NA	NA	NA	1.2

Notes:

NA - Not analyzed
U - Analyte not detected
J - Result may be estimated
R-Unreliable result, rejected data.
UJ-Analyte not detected, result may be estimated
Shading Indicates Detection

mg/kg-milligrams per kilogram
mg/L-milligrams per liter
µg/kg-micrograms per kilogram
µg/L-micrograms per liter
pH-pH units

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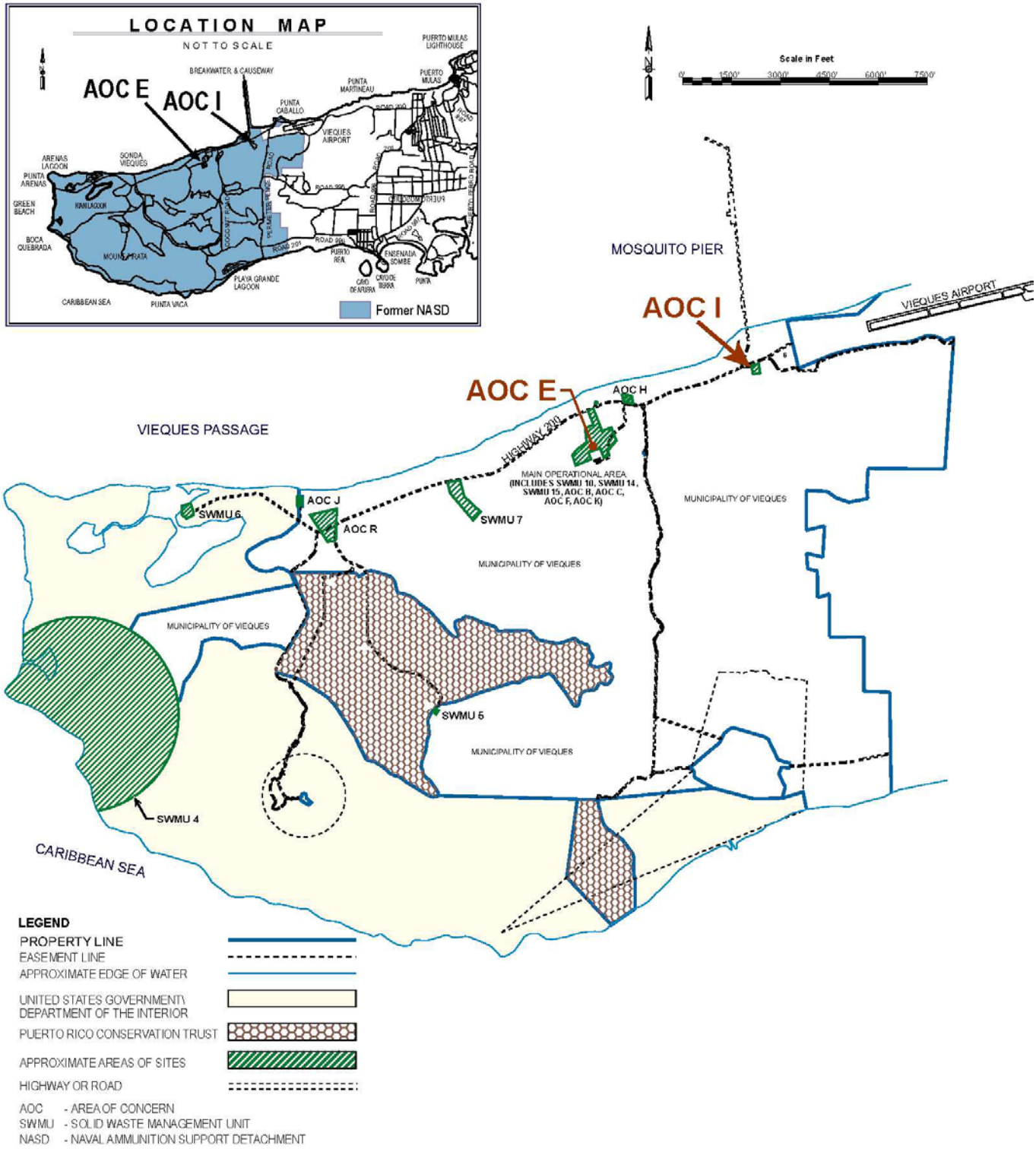
ES032009002TPA



SOURCE:
VIEQUES NASD SURVEY LAND TRANSFER & DISPOSAL OVERALL LOCATION SURVEY
PREPARED BY GLENN & SADLER AND LUIS BERRIOS MONTES & ASSOCIATES

CH2MHILL

FIGURE ES-1
AOC E and AOC I Site Location Map
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

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SAP Worksheet #1 — Title and Approval Page

Final
In-Situ Remediation Pilot Studies,
Areas of Concern E & I - Former Naval Ammunition Support Detachment
Vieques, Puerto Rico
February 2010

Prepared for:
Department of the Navy
Naval Facilities Engineering Command
Atlantic Division
6506 Hampton Boulevard
Norfolk, VA 23508-1278

Prepared by:

CH2MHILL

5700 Cleveland Street, Suite 101
Virginia Beach, VA 23462
Office phone # 757-671-6219

Prepared under:
Navy CLEAN III Program
Contract N62470-02-D-3052
Contract Task Order – 007

QA REVIEW SIGNATURE:

BRETT DOERR
VIEQUES ACTIVITY QUALITY MANAGER

OTHER APPROVAL SIGNATURES:

KEVIN CLOE
NAVFAC – REMEDIAL PROJECT MANAGER

DANIEL RODRIGUEZ
USEPA REGION 2 – REMEDIAL PROJECT MANAGER

WILMARIE RIVERA
PREQB – REMEDIAL PROJECT MANAGER

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SAP Worksheet #2 — SAP Identifying Information

Site Name/Number: Area of Concern (AOC) E and AOC I at the former Naval Ammunition Support Detachment (NASD), Vieques, Puerto Rico
Operable Unit (OU):
Contractor Name: CH2M HILL
Contract Number: N62470-02-D-3052
Contract Title: Navy Comprehensive Long-term Environmental Action—Navy (CLEAN) Program III
Work Assignment Number (optional): Contract Task Order (CTO) 007 (Pilot Study Sampling and Analysis Plan [SAP])

1. This SAP was prepared in accordance with the requirements of the Uniform Federal Policy for Quality Assurance Plans (UFP-QAPP) (USEPA, 2005) and United States (U.S.) Environmental Protection Agency (USEPA) Guidance for QAPPs, USEPA QA/G-5, Quality Assurance Management Section (QAMS) (USEPA, 2002)
2. Regulatory program: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
3. This SAP is a project-specific SAP
4. Dates of scoping sessions:

Scoping Session	Date
Environmental Technical Subcommittee Meeting—Vieques, Puerto Rico	January 28, 2009
Environmental Technical Subcommittee Conference Call	February 26, 2009

5. Dates and titles of any SAP documents written for previous site work that are relevant to the current investigation.

Title	Date
Master QAPP (MQAPP[1]), Environmental Restoration Program (ERP), Vieques, Puerto Rico	May 2007

[1] Referred to as MQAPP throughout the document.

SAP Worksheet #2 — SAP Identifying Information (continued)

6. Organizational partners (stakeholders) and connection with lead organization:
   - **USEPA Region 2 –** Regulatory stakeholder overseeing CERCLA Vieques environmental restoration program (ERP) implemented by lead organization
   - **Puerto Rico Environmental Quality Board (PREQB) –** Regulatory stakeholder overseeing CERCLA Vieques ERP implemented by lead organization
7. Lead organization (see Worksheet #7 for detailed list of data users):
   - U.S. Department of Navy (Navy).
8. The omitted SAP elements excluded and provide an explanation for their exclusion below:
   - Crosswalk table is excluded as all required information is provided in this SAP.

SAP Worksheet #3 — Distribution List

Name of SAP Recipients	Title/Project Role	Organization	Telephone Number (Optional)	E-mail Address or Mailing Address	D	DF	F
Kevin Cloe	Vieques Remedial Project Manager (RPM)/ Lead Agency Point of Contact (POC)	Navy	757-322-4736	kevin.cloe@navy.mil	A	CL	A
Chris Penny	Vieques Program Coordinator/No project-specific role	Navy	757-322-4815	christopher.penny@navy.mil	CL	CL	CL
Dan Hood	Vieques RPM/No project-specific role	Navy	757-322-4630	daniel.r.hood@navy.mil	CL	CL	CL
Madeline Rivera	Vieques Environmental Restoration Program Site Manager /On-island coordination	Navy	757-348-2689 (cell)	llamasmad@gmail.com	A		A
John Noles	Biologist/Technical input	Navy	757-322-4891	john.noles@navy.mil	HC		A
Bonnie Capito	Librarian and Records Manager/Final document archiving	Navy	757-322-4785	bonnie.capito@navy.mil			A
Stephen Brand	Project Manager	CH2M HILL	757-671-6211	stephen.brand@ch2m.com,			A
Dia Whitaker	Field Team Leader/Site Safety Coordinator	CH2M HILL	813-874-6522 (X4226-work) 813-426-4989-cell	dia.whitaker@ch2m.com			A
John Swenfurth	Project Manager	CH2M HILL	813-874-0777	john.swenfurth@ch2m.com	A	A	A
Susanne Borchert	Senior Technologist	CH2M HILL	815-233-1051	susanne.borchert@ch2m.com			A
Kui Tan	Project Engineer	CH2M HILL	713-462-0169	kui.tan@ch2m.com			A
Mike Zamboni	Project Chemist	CH2M HILL	703-376-5301	mike.zamboni@ch2m.com			A
Brett Doerr	Contractor Environmental Manager/ Navy contractor primary POC	CH2M HILL	757-671-6219	brett.doerr@ch2m.com	A	A	A
Ed Lawler	Project Manager	Mitkem Laboratories, Inc.	(401) 732-3400	elawler@mitkem.com			HC
Greg Davis	President	Microbial Insights, Inc.	(865) 573-8188	gdavis@microbe.com			HC
Dulce Litchfield	Project Manager	Spectrum Laboratories	(413) 789-9018	dlitchfield@spectrum-analytical.com			HC
Laura Maschoff	Project Manager	DataQual Environmental Services, LLC	(314) 330-1327	dataqual@charter.net			CD
Daniel Rodriguez	Vieques RPM/ Regulatory agency POC	USEPA	787-741-5201 787-671-9879 (cell)	rodriguez.daniel@epa.gov	A	CL	A
Carl Soderberg	Caribbean Environmental Protection Division Director	USEPA	787-977-5814	soderberg.carl@epa.gov	CL		CL

SAP Worksheet #3 — Distribution List (continued)

Name of SAP Recipients	Title/Project Role	Organization	Telephone Number (Optional)	E-mail Address or Mailing Address	D	DF	F
Sergio Lopez	QC Specialist/Technical input and draft document review	USEPA	732-321-6778	lopez.sergio@epa.gov	A		A
Michael Sivak	Human Health Risk Assessment (HHRA) Lead/Technical input and draft document review	USEPA	212-637-4310	sivak.michael@epa.gov	A		A
Diana Cutt	Geology/Hydrogeology Lead/Technical input and draft document review	USEPA	212-637-4311	cutt.diana@epa.gov	A		A
Mindy Pensak	Ecological Risk Assessment (ERA) Lead/Technical input and draft document review	USEPA	732-321-6705	pensak.mindy@epa.gov	A		A
John Fellinger	Technical Support Consultant for USEPA/USEPA contractor primary POC	TechLaw	856-878-0988	jfellinger@techlawinc.com	A		A
Pedro J. Nieves, Esq.	President/No project-specific role	PREQB	787-767-8056	pedronieves@jca.gobierno.pr	CL		CL
Wilmarie Rivera	Vieques RPM/ Regulatory agency POC	PREQB	787-767-8181 (x6141) (work) 787-365-8573 (cell)	wilmarierivera@jca.gobierno.pr	A	CL	A
Katarina Rutkowski	Technical Support Consultant for Environmental Quality Board (EQB)/EQB contractor primary POC	TRC	860-298-6202	krutkowski@trcsolutions.com	A		A
Andrew Smyth	Technical Support Consultant for EQB//EQB contractor Project Manager (PM)	TRC	978-656-3568	asmyth@trcsolutions.com	A		A
Matt Connolly	Refuge Manager/No project-specific role	USFWS	787-741-2138	matt_connolly@fws.gov			A
Susan Silander	Caribbean Islands Refuges Supervisor/No project-specific role	USFWS	787-851-7258 (x38)	susan.silander@fws.gov	CL		CL
Richard Henry	Vieques RPM/ Land management agency POC/No project-specific role	USFWS	732-906-6987	richard_henry@fws.gov	A	CL	A
Felix Lopez Arroyo	Environmental Contaminants Specialist/Technical input and draft document review/No project-specific role	USFWS	787-851-7297(x226)	felix_lopez@fws.gov	A		A
William Tucker	Technical Support Consultant for USFWS/USFWS contractor primary POC/No project-specific role	MACTEC	352-332-3318	watucker@mactec.com	A		A
Diane Wehner	Regional Resource Coordinator/Technical input and draft document review/No project-specific role	NOAA	732-872-3030	diane.wehner@noaa.gov	A		A
Roberta W. Britton	Not Applicable (N/A)	Restoration Advisory Board (RAB)	978-463-9660	bdbritt7@gmail.com		CD	
Michael P. Connelly Pagán	N/A	RAB	787-741-4442	mpcbieke@yahoo.com		A	

SAP Worksheet #3 — Distribution List (continued)

Name of SAP Recipients	Title/Project Role	Organization	Telephone Number (Optional)	E-mail Address or Mailing Address	D	DF	F
Michael Diaz	N/A	RAB	787-667-2804	diazmmdo@aol.com		CD	
Wanda Bermudez	NA	RAB	787-435-2841	wbromero@yahoo.com		CD	
Colleen McNamara	N/A	RAB	787-380-2545	lacolina@hughes.com		A	
Stacie D. Notine	N/A	RAB	N/A	N/A		HC	
Jorge Fernandez Porto	NA	RAB	787-726-2839	jfporto@onelinkpr.net		CD	
Hector Julian Camacho	N/A	RAB	787-741-8261	vieques357@yahoo.com		HC	
Lionel Sanchez	NA	RAB	787-241-0063	sanchezcarambot@yahoo.com		HC	
Lirio Marquez D'Acunti	NA	RAB	787-726-2839	liriomarquez@gmail.com		None	

A = All DF = Draft Final
CL = Cover Letter F = Final
CD = Compact Disc HC = Hard Copy
D = Draft

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SAP Worksheet #4 — Project Personnel Sign-Off Sheet

Name	Organization/Title/Project Role	Telephone Number (optional)	Signature/email receipt	SAP Section Reviewed	Date SAP Read
Kevin Cloe	NAVFAC Atlantic/ Vieques RPM/ Lead agency POC	757-322-4736			
Daniel Rodriguez	USEPA/ Vieques RPM/ Regulatory agency POC	787-741-5201 787-671-9879 (cell)			
Wilmarie Rivera	PREQB/Vieques RPM/ Regulatory agency POC	787-767-8181 (x6141)			
Paul Favara	CH2M HILL/Quality Assurance Officer (QAO)/SAP review	352-335-5877 (x52396)			
Anita Dodson	CH2M HILL/Navy Program Chemist/ SAP review	757-671-6218			
Brett Doerr	CH2M HILL/ Contractor Environmental Manager/Navy contractor primary POC	757-671-6219			
John Swenfurth	CH2M HILL/Contractor PM/Logistics and administration	813-874-6522 (x4127) 813-390-4734 (cell)			
Mark Orman	CH2M HILL/Contractor health and safety Lead/Health and safety officer	414-847-0597 414-712-4138 (cell)			
Juan Acaron	CH2M HILL/Environmental Information Specialist (EIS)/Data tracking and management	352-384-7002 352-214-2814(c)			
Stephen Brand	CH2M HILL/Contractor PM	813-874-6522 (x4317) 813-220-3221 (cell)			
Dia Whitaker	FTL/SSC	813-874-6522 (x4226) 813-426-4989			
Mike Zamboni	CH2M HILL/Project Chemist	703-376-5301			
Ed Lawler	Mitkem/Project Manager	401-732-3400			
Greg Davis	Microbial Insights, Inc./President	865-573-8188			
Dulce Litchfield	Spectrum Laboratories/Project Manager	413-789-9018			
Susanne Borchert	CH2M HILL Senior Technologist	815-233-1051			
Kui Tan	CH2M HILL Project Engineer	713-462-0169			
Bhavana Reddy	CH2M HILL Project/Data Manager	703-462-3784			
TBD	CH2M HILL/Field Team				

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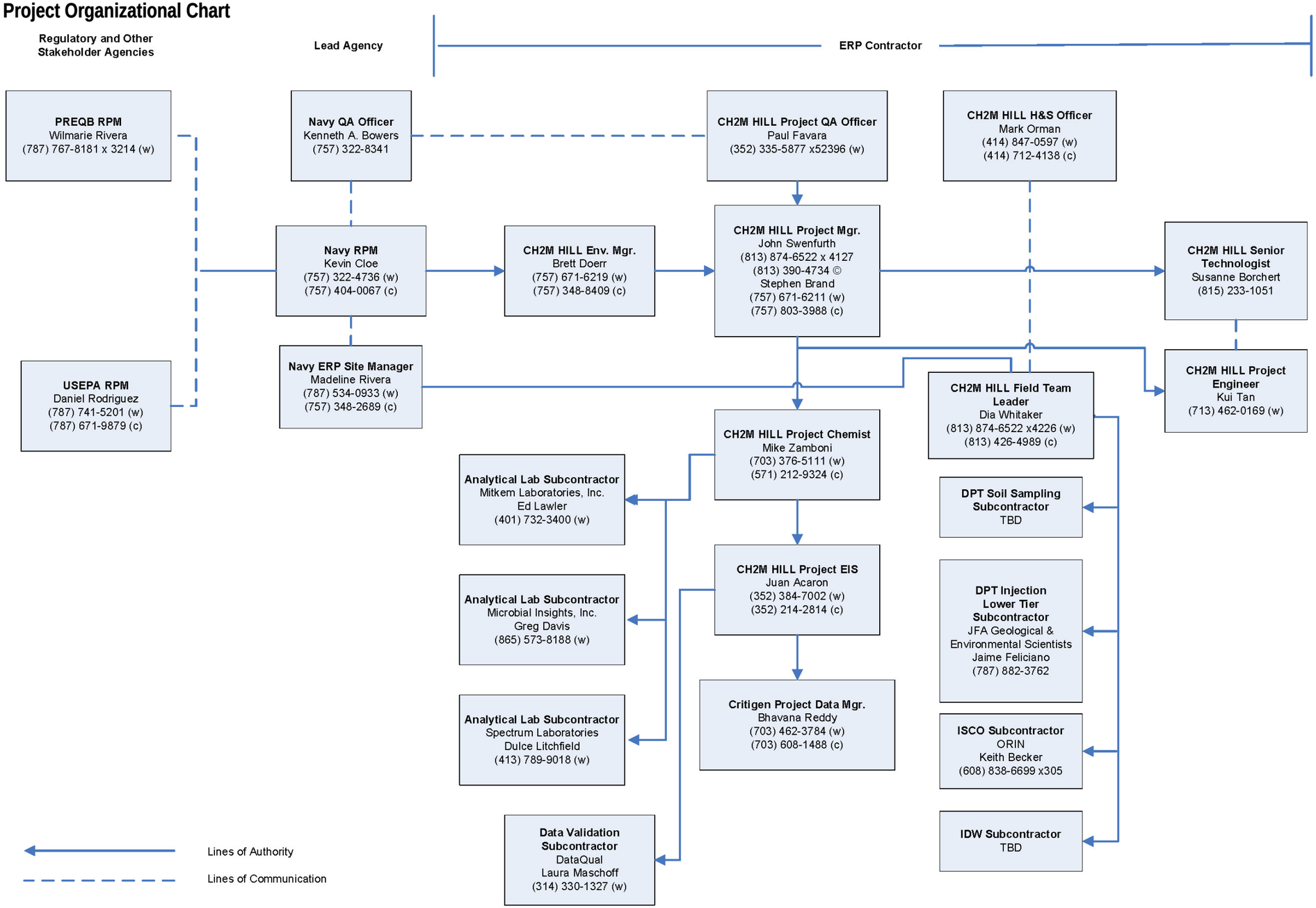
SAP Worksheet #5 — Project Organizational Chart



SAP Worksheet #5
Project Organizational Chart
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

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SAP Worksheet #6 — Communication Pathways

Communication Drivers	Responsible Affiliation	Name	Phone Number	Procedure
Communication to/from Navy (e.g., submission of SAP for review; receipt of regulatory comments, etc.)	Navy RPM	Kevin Cloe	757-322-4736	Primary POC for Navy (via e-mail, telephone, hardcopy, or in-person, as warranted); can delegate communication to other internal or external points of contact.
Communication to/from USEPA (e.g., receipt of SAP for review; submission of USEPA comments)	USEPA RPM	Daniel Rodriguez	787-741-5201 787-671-9879 (cell)	Primary POC for USEPA (via e-mail, telephone, hardcopy, or in-person, as warranted); can delegate communication to other internal or external points of contact.
Communication to/from PREQB (e.g., receipt of SAP for review; submission of PREQB comments)	PREQB RPM	Wilmarie Rivera	787-767-8181 (x6141)	Primary POC for PREQB (via e-mail, telephone, hardcopy, or in-person, as warranted); can delegate communication to other internal or external points of contact.
Navy Quality Assurance (QA)/Quality Control (QC) input	Navy QAO	Sherri Eng	757-322-4366	Provides review comments to Navy contractor on pre-draft SAP via e-mail through Kevin Cloe. Provides overall Navy guidance via direct communication with Navy contractor QAO, as warranted.
Communication to/from Navy contractor (e.g., submission of SAP for review; receipt of regulatory comments, updates on project progress, communication of stakeholder expectations, etc.)	CH2M HILL Environmental Manager	Brett Doerr	757-671-6219	Primary POC for Navy contractor (via e-mail, telephone, hardcopy, or in-person, as warranted); can delegate communication to other contractor staff, as appropriate.
Project administration and logistics	CH2M HILL PM	John Swenfurth	813-874-6522 (x4127) 813-390-4734 (cell)	Direct communication (via e-mail, telephone, hardcopy, or in-person, as warranted) to/from Navy contractor project staff to ensure appropriate project implementation.
Health and safety expectations and procedures	CH2M HILL Health and Safety Officer	Mark Orman	414-847-0597 414-712-4138 (cell)	Review of Health and Safety Plan (HASP). Direct communication (via e-mail, telephone, hardcopy, or in-person, will be notified within 24 hours of incident) to/from Navy contractor project staff to ensure implementation of appropriate health and safety procedures.
Implementation of pilot study injection and sampling activities; SAP changes in the field	CH2M HILL FTL	Dia Whitaker	813-874-6522 (x4226) 813-426-4989	Documentation of deviations from work plan made in field logbooks and rationale for deviations, made within 24 hours of deviation; assistance in material procurement and delivery; injection oversight and implementation; deviations made only with approval from contractor PM and/or environmental manager. The EPA and PREQB RPMs will be notified within 24 hours of significant SAP changes in the field.
Field corrective actions	CH2M HILL FTL	Dia Whitaker	813-874-6522 (x4226) 813-426-4989	See Worksheet 32 Assessment Findings and Corrective Action (CA) Responses and Worksheet 32-1 CA Form. The EPA and PREQB RPMs will be notified within 24 hours of significant field corrective actions.

SAP Worksheet #6 — Communication Pathways (continued)

Communication Drivers	Responsible Affiliation	Name	Phone Number	Procedure
Daily Field Progress Reports	CH2M HILL Field Team Leader (FTL)	Dia Whitaker	813-874-6522 (x4226) 813-426-4989	FTL will e-mail or fax daily field progress reports to contractor PMs weekly; telephone communication with PMs on as-needed basis
Ensure staff health and safety in the field	CH2M HILL Site Safety Coordinator (SSC)	Dia Whitaker	813-874-6522 (x4226) 813-426-4989	Daily safety tailgates; daily observations; real-time discussions of observations and changes to be implemented with field staff.
Data tracking from collection through upload to database	CH2M HILL EIS	Juan Acaron	352-384-7002 352-214-2814(c)	EIS will track data from sample collection through upload to database, ensuring QAPP requirements are met by laboratory and field staff. Tracking involves receipt of electronic and hardcopy data from laboratory and data validator. EIS communicates with CH2M HILL project chemist, laboratory PM, and data validator PM, as warranted, to ensure adherence to project analysis and validation requirements. EIS also coordinates data upload with contractor database manager.
Uploading project data and maintaining the database to ensure data are stored properly and can be retrieved by the EIS.	Critigen Database Manager	Bhavana Reddy	703-471-1441	Once contractor chemist ensures data are appropriate for upload to database, EIS submits data electronically to contractor database manager, who uploads data to database.
Reporting Lab Data Quality Issues	Laboratory PM (Mitkem Laboratories); Laboratory President (Microbial Insights, Inc.)	Ed Lawler; Greg Davis	401-732-3400 865-573-8188	All QA/QC issues with project field samples will be reported by the lab to the EIS, Project Chemist, and Contractor QAO via e-mail within 2 business days.
Quality Control on Laboratory Data	CH2M HILL Project Chemist	Michael Zamboni	703-376-5301	See Worksheets 24, 25, and 28 for analytical CAs.
In-situ Injection Technical Support and Reporting	CH2M HILL Senior Technologist; Project Engineer	Susanne Borchert; Kui Tan	815-233-1051; 713-462-0169	Data evaluation, analysis, and reporting
Validated data	Data Validator PM (DataQual)	Laura Maschoff	314-330-1327	Data validator provides data validation reports (electronic and hardcopy) that provide the data qualifiers and associated explanations.
Release of analytical data for upload to database	CH2M HILL Project Chemist	Michael Zamboni	703-376-5301	Upon review of validated data to ensure adherence to project requirements, project chemist communicates via e-mail to EIS that data are ready for release (i.e., upload to database).

SAP Worksheet #7 — Personnel Responsibilities and Qualifications Table

Name	Title	Organizational Affiliation	Responsibilities	Education and Experience Qualifications[1]
Kevin Cloe	Vieques RPM	Navy	Environmental restoration program (ERP) activities implemented under this SAP	M.E. Environmental Engineering B.S. Civil Engineering 18 years experience
Sherri Eng	QAO	Navy	Navy review of SAP and QA input	B.S. Chemistry 21 years experience
Madeline Rivera	Vieques ERP Site Manager	Navy	On-island Navy liaison; provides logistical support for implementation of environmental restoration program activities under this SAP	M.S. Engineering Administration B.S. Chemical Engineering, REM, UXO Technician I 15 years experience
Brett Doerr	Environmental Manager	CH2M HILL	Responsible for ERP at Vieques; primary Navy contractor point of contact (POC); assists in data evaluation and interpretation; reviews report	M.S. Environmental Science/Hydrogeology B.S. Chemistry 17 years experience
Paul Favara	Project QAO	CH2M HILL	Oversees compliance with program and project-specific quality requirements	M.S. Environmental Engineering B.S. Chemistry 22 years experience
John Swenfurth	PM	CH2M HILL	Project administration; coordinates staffing; monitors project performance; directs and oversees project staff	M.S. Hydrogeology 12 years experience
Susanne Borchert	Senior Technologist	CH2M HILL	As the technical lead, leads selection of in-situ remediation technology for pilot testing; oversees preparation of reports; and provides recommendations on path forward	M.S. Structural and Applied Geology B.S. Earth and Planetary Sciences 19 years experience
Kui Tan	Project Engineer	CH2M HILL	Prepares injection protocol portion of SAP; performs data evaluation and analysis; assists in report writing	PhD. Civil (Environmental Engineering) M.S. Environmental Chemical Engineering B.S. Chemistry 10 years experience

SAP Worksheet #7 — Personnel Responsibilities and Qualifications Table (continued)

Name	Title	Organizational Affiliation	Responsibilities	Education and Experience Qualifications[1]
Mike Zamboni	Project Chemist	CH2M HILL	Establishes laboratory scope of work; ensures selected laboratory can meet project-required analytical protocol; primary communications with laboratory and data validator; performs data quality evaluation to determine availability of analytical data	B.S. Chemistry 7 years experience
Stephen Brand	PM	CH2M HILL	Project administration; coordinates staffing; monitors project performance; directs and oversees project staff	M.S. Geology 18 years experience
Mark Orman	Health and Safety Officer	CH2M HILL	Responsible for overall Navy CLEAN program health and safety performance; reviews project-specific HASP; interacts with SSC to ensure project-specific safety of field personnel	B.S. Environmental Science CSP, CHMM, ARM 15 years experience
Dia Whitaker	FTL and SSC	CH2M HILL	Supervises field injection, sampling and coordinates all field activities; ensures onsite compliance with work plan; oversees and ensures safety of onsite personnel	B.S. Geology 6 years experience
Juan Acaron	Environmental Systems Specialist	CH2M HILL	Manages sample tracking; coordinates assimilation of data from field collection through analysis, validation, and upload to environmental database; performs data queries for data evaluation and report writing	B.S. Chemistry 4 years experience
Bhavana Reddy	Database Manager	Critigen	Uploads validated data to environmental database	B.A. Business Administration and Accounting 13 years experience
Greg Davis	President	Microbial Insights, Inc.	Responsible for laboratory QA program and review of QC data for microbial parameters (PLFA and qPCR) analysis	NA
Sharyn Lawler	Quality Assurance Director	Mitkem Laboratories	Responsible for laboratory QA program and review of QC data	B.S. Coastal Plant Ecology 26 years experience
Cassie Mosher	Organics Department Manager	Mitkem Laboratories	Responsible for oversight, QC, and data review of organics laboratory	Certificate of Chemical Technology 21 years experience
Dawne Smart	Inorganics Department Manager	Mitkem Laboratories	Responsible for oversight, QC, and data review of inorganics laboratory	Certificate of Chemical Technology 22 years experience
Ed Lawler	Project Manager	Mitkem Laboratories	Laboratory POC and overall manager for analytical work	B.S. Environmental Sciences 21 years experience

SAP Worksheet #7 — Personnel Responsibilities and Qualifications Table (continued)

Name	Title	Organizational Affiliation	Responsibilities	Education and Experience Qualifications[1]
Laura Maschoff	Project Manager and Data Validator	Data Validation Subcontractor (DataQual)	Responsible for validating analytical data in accordance with project-specific UFP-SAP	B.S. Biology 14 years experience
Jackie Cleland	Data Validator	Data Validation Subcontractor (DataQual)	Responsible for validating analytical data in accordance with project-specific UFP-SAP	B.S. Chemistry 17 years experience
Jaime Feliciano	Manager, JFA Geological and Environmental Scientists	Direct Push Drilling Subcontractor	Responsible for performing direct-push drilling for injection points installation and conversion to temporary injection wells for vadose zone nitrate trickle-infiltration purpose at AOC E; responsible for direct push injection under the oversight of ORIN and CH2M HILL FTL	M.S. Geology 16 years experience
Keith Becker	Manager, ORIN	Injection Subcontractor	Responsible for implementation of injection activities at both temporary injection points at AOC E and existing monitoring wells (at AOC E and AOC I), in accordance with UFP-SAP	B.S. Forestry/Soils and Environmental Management 13 years experience
TBD	TBD	Investigation-derived Waste (IDW) Subcontractor	Responsible for transport and disposal of IDW deemed necessary for offsite disposal	

1 Resumes are maintained by the individuals' organizations and are available upon request; upon execution of the project, staff may be removed (if unnecessary to project execution) and other staff may be added or substituted, as necessary and available.

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SAP Worksheet #8 — Special Personnel Training Requirements Table

Project Function	Specialized Training by Title or Description of Course	Training Provider	Training Date	Personnel/Groups Receiving Training	Personnel Titles/ Organizational Affiliation	Location of Training Records/Certificates
Field activities	Hazwoper 40-hour Training, 8 hour refreshers, as applicable	Various qualified training organizations	Training of CH2M HILL and subcontractors will be verified as current prior to starting field activities by SSC	All field personnel	FTLs, field team members, and SSC (CH2M HILL personnel); drilling and/or injection subcontractor; IDW subcontractor; and surveying subcontractor	CH2M HILL Human Resources Department for CH2M HILL personnel; subcontractor organizations for field subcontractors
Field activities	CPR/First Aid Training	Various qualified training organizations	Training will be verified as current prior to starting field activities	CH2M HILL SSC	CH2M HILL SSC	CH2M HILL Human Resources Department
Field activities	SSC-hazardous waste (SSC-HW) training	Various qualified training organizations	Training will be verified as current prior to starting field activities by SSC.	CH2M HILL SSC	CH2M HILL SSC	CH2M HILL Human Resources Department

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SAP Worksheet #9a — Project Scoping Session Participants Sheet

Project Name: In-Situ Remediation Pilot Studies	
Projected Date(s) of Sampling: January 2010 through January 2012	**Site Name:** AOC E and AOC I
PM: John Swenfurth	**Site Location:** Vieques, Puerto Rico
Dates of Session: January 28, 2009 **Scoping Session Purpose:** Discuss technical issues associated with proposed in-situ remediation pilot studies	

Name	Title	Affiliation	Phone #	E-mail Address	Project Role
Kevin Cloe	Vieques RPM	Navy	757-322-4736	Kevin.cloe@navy.mil	Primary Navy POC.
Michael Sivak	Human Health Risk Assessment Lead	USEPA	212-637-4310	Sivak.michael@epa.gov	Technical input and review of human health risk evaluation
Diana Cutt	Geology/Hydrogeology Lead	USEPA	212-637-4311	Cutt.diana@epa.gov	Technical input and review of geology/hydrogeology
Wilmarie Rivera	Vieques RPM	PREQB	787-767-8181 x 6141	wilmarierivera@jca.gobierno.pr	Primary PREQB POC.
Katarina Rutkowski	Technical Support Contractor Human Health Risk Assessment Lead	TRC	860-298-6202	krutkowski@trcsolutions.com	Technical input and review of human health risk aspects on behalf of EQB. Primary TRC POC.
Richard Henry	Vieques RPM	USFWS	732-906-6987	Richard_henry@fws.gov	Primary USFWS POC/No project-specific role
Felix Lopez	Environmental Contaminants Specialist	USFWS	787-851-7297 ext 226	Felix_lopez@fws.gov	No project-specific role
Daniel Rodriguez	Vieques RPM	USEPA	787-741-5201 787-671-9879 (cell)	Rodriguez.daniel@epamail.gov	Primary USEPA POC
Laura Pugh	Senior Staff Consultant	Tech Law	763-208-2828	lpugh@techlawinc.com	Technical input and review on behalf of EPA. Primary Tech Law POC
Madeline Rivera	Vieques Environmental Restoration Program Site Manager	NAVFAC	757-348-2689 (cell)	llamasmad@gmail.com	On-island coordination

SAP Worksheet #9a — Project Scoping Session Participants Sheet (continued)

Project Name: In-Situ Remediation Pilot Studies	
Projected Date(s) of Sampling: January 2010 through January 2012	**Site Name:** AOC E and AOC I
PM: John Swenfurth	**Site Location:** Vieques, Puerto Rico
Dates of Session: January 28, 2009 **Scoping Session Purpose:** Discuss technical issues associated with proposed in-situ remediation pilot studies	

Name	Title	Affiliation	Phone #	E-mail Address	Project Role
Brett Doerr	Environmental Manager	CH2M HILL	757-671-6219	Brett.doerr@CH2M.com	Scope development and technical review. Primary CH2M HILL POC.
John Swenfurth	PM	CH2M HILL	813-874-6522 x 4127	John.swenfurth@CH2M.com	Project management
Mike Zamboni	Project Chemist	CH2M HILL	703-376-5111	Mike.zamboni@ch2m.com	Sampling and lab coordination
Stephen Brand	PM	CH2M HILL	757-671-6211	Brand.stephen@ch2m.com	Project management

Comments/Decisions: See meeting minutes from January 28, 2009 Environmental Restoration Program Technical Subcommittee Meeting below.

Action Items: See below

Consensus Decisions: See below

SAP Worksheet #9a — Project Scoping Session Participants Sheet (continued)

Excerpt from the January 28, 2009 Draft Environmental Restoration Program Technical Subcommittee Meeting Minutes

AOC E and AOC I Pilot Studies

One of the primary issues discussed was whether such small areas and low concentrations of contaminants warrant a pilot study. CH2M HILL stated that this was considered and discussed with the Navy, but in this instance was determined to be warranted (as designed in the memoranda) because the Navy no longer has a presence at these sites and therefore would be required to implement controls until such time as the contaminant concentrations declined to the MCLs. Natural attenuation modeling of the current contaminant concentrations suggests this may require 10 to 20 years. Therefore, there is significant benefit to being able to return the sites unencumbered (i.e., without restrictions) to the Municipality in a shorter timeframe. In addition, CH2M HILL noted that there are many technologies that can reduce high concentrations of contaminants to low concentrations, but that it is very difficult to reduce already low concentrations to even lower concentrations or non-detect. For these reasons, pilot studies that do not require additional drilling/well installation may be cost-effective and appropriate for these sites.

Another concern stated by EPA is the proposed use of the monitoring wells as injection points. If the monitoring wells were sampled after being used as injection points, it is possible that the samples collected may contain the oxidant due to the water displacement that occurs during injection. This issue was also considered by CH2M HILL prior to proposing it in the memos. The reason it was proposed in the memos is threefold:

a. The cost of installing additional injection points may make the cost of the pilot studies outweigh the benefit. Cannot use direct push for injection because of depth of groundwater; would need to install injection wells, which results in very high cost.
b. The area of contamination is so small that if injection points were installed, they would be within several feet of the monitoring wells. Therefore, the concern about sampling the oxidant may still exist.
c. The water-bearing unit is not highly conductive, especially at AOC E, where there is an abundance of clay in the saturated zone. This would likely make the radius of influence around each injection point relatively small. Therefore, it was considered advantageous to inject throughout the area of contamination (vs just upgradient), which is approximated by the spatial distribution of the monitoring wells proposed for injection.

EPA asked if CH2M HILL has any knowledge of or experience injecting into the same wells that will be used for subsequent monitoring. Brett Doerr/CH2M HILL will bring the question to the internal technologists and report back to the team.

A concern raised by TRC is whether the proposed ISCO injection could kill the microbes instead of stimulating their growth. Brett Doerr/CH2M HILL will bring the question to the internal technologists and report back to the team.

SAP Worksheet #9a — Project Scoping Session Participants Sheet (continued)

EPA will make a determination of whether they will accept using the same wells for injection and monitoring. The Navy stated that if that is not permissible, then the Navy may not conduct the pilot study because it will not be cost efficient to install injection wells and some of the same issues raised above may still apply. CH2M HILL noted that if a feasibility study is conducted, it will likely conclude that monitored natural attenuation is the preferred alternative. It was also suggested that the Navy could consider just suspending the socks in the wells and eliminating the ISCO step. Another potential is to inject in the monitoring wells and then wait a much longer period before sampling.

SAP Worksheet #9b — Project Scoping Session Participants Sheet

Project Name: In-Situ Remediation Pilot Studies	
Projected Date(s) of Sampling: January 2010 through January 2012	**Site Name:** AOC E and AOC I
PM: John Swenfurth	**Site Location:** Vieques, Puerto Rico
Dates of Session: February 26, 2009 **Scoping Session Purpose:** Reach consensus on whether pilot study can proceed based on the general approach of the pilot study discussed during the January 2009 meeting, primarily around the use of monitoring wells as injection points	

Name	Title	Affiliation	Phone #	E-mail Address	Project Role
Diana Cutt	Geology/Hydrogeology Lead	USEPA	212-637-4311	cutt.diana@epa.gov	Technical input and review of geology/hydrogeology
Katarina Rutkowski	Technical Support Contractor Human Health Risk Assessment Lead	TRC	860-298-6202	rutkowski@trcsolutions.com	Technical input and review of human health risk aspects on behalf of EQB. Primary TRC POC.
Brett Doerr	Environmental Manager	CH2M HILL	757-671-6219	brett.doerr@ch2m.com	Scope development and technical review. Primary CH2M HILL POC
Susanne Borchert	Senior Technologist	CH2M HILL	815-233-1051	susanne.borchert@ch2m.com	CH2M HILL technical lead of pilot studies

Comments/Decisions: See telephone conversation record from February 26, 2009 conference call.

Action Items: See below.

Consensus Decisions: See below.

SAP Worksheet #9b — Project Scoping Session Participants Sheet (continued)

Excerpt from the February 26, 2009 Telephone Conversation Record

AOC E and AOC I Pilot Studies

Objective of Call – Attempt to reach consensus on whether pilot study can proceed and on the general approach of the pilot study.

Consensus Agreement – The call participants concurred that due to the relatively unique circumstances at the sites (i.e., very small areas of contamination, high costs to install separate injection wells, close proximity new injection wells would be to monitoring wells), the pilot study can proceed as generally proposed in the pilot study memoranda, specifically with respect to using the existing monitoring wells as injection wells and monitoring wells. The following are to be considered when developing the UFP-SAP:

1. The potential for water displacement during injection is to be minimized. The recommended approach should consider gravity-feed or very low pressure injection.

2. The approach should maximize the confidence that the monitoring data being collected are truly representative of the aquifer conditions, not of the injected material. For example:

    a. Propose a time interval between injection and sampling that is considered sufficient for the injected material to dissipate.

    b. Propose geochemical parameters to be sampled pre- and post-injection that will aid in this determination, using multiple lines of evidence to increase the understanding of the nature of the groundwater being extracted. For example, field test for persulfate prior to sampling, to ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate)

3. Include means of determining contaminant rebound; for example, with sampling frequency and geochemical trends.

4. At AOC E include visual monitoring for potentially re-occurring sheen due to NAPL that was present at this former UST site in the past and the relatively high-magnitude groundwater fluctuations.

The in-situ remediation pilot studies proposed for Vieques AOCs E and I as described in the November and December 2008 documents focused on the conceptual approach and, as such, did not include the details such as the basis for the amount of oxidant being injected, the injection protocol (quantity of liquids to be injected, flow rates, injection pressures), or the quantities of oxygen-releasing reagents to be used in the pilot study. These details will be included in the pilot study SAP.

SAP Worksheet #10a — AOC E Problem Definition

Introduction

This worksheet provides a summary of site background and key elements of the conceptual site model (CSM), followed by a narrative description of the problems to be addressed during the proposed pilot study.

The proposed pilot study activities include installing a network of temporary, unsaturated zone injection points by direct push technology (DPT), delivering nitrate to the unsaturated zone soil via the temporary injection points, performing In-situ Chemical Oxidation (ISCO) injections and Enhanced In-situ Bioremediation (EISB) via existing wells for groundwater remediation, collecting post-injection confirmatory soil samples, and collecting pre- and post-injection groundwater samples. CH2M HILL will perform these activities to evaluate the effectiveness of the pilot study in meeting the pilot study preliminary remediation goals (PRGs) that are discussed herein.

Background

This section provides a summary of the site background, key elements of the CSM (including the site setting and history, geology, hydrogeology), a summary of the baseline human health risk assessment (HHRA) and ecological risk assessment (ERA), pilot study PRGs, the pilot study objectives, and the pilot study approach. Detailed information about the site's characteristics can be found in the Remedial Investigation (RI) Report for AOC E (CH2M HILL, 2008a).

Site Setting and History

AOC E is located at the Former NASD in Vieques, Puerto Rico and occupies less than about a tenth of an acre. AOC E is the site of a former 500-gallon underground storage tank (UST) associated with a former vehicle maintenance operation within the main operational area (i.e., Public Works) of the Former NASD. Figure 1 shows the location of AOC E within the Former NASD. The UST was in service between about 1970 and 1996, during which time it was used to store used oil generated from vehicle maintenance activities that took place at the vehicle maintenance and transportation shop (Building 2016). Specifically, oil removed from vehicles on the vehicle maintenance platform was drained to the UST via an underground pipe between the platform and the UST. In 1996, the UST was removed and replaced with a 500-gallon aboveground storage tank (AST) that, in turn, was removed in 2001. Figure 2 shows the site location map, including site features and locations of monitoring wells.

The topography at AOC E is flat. Stormwater at the site has been observed to pond rather than run off. To the north of the site, a stormwater ditch channels stormwater runoff toward the north from the Public Works access roads. No surface water bodies are located at or immediately adjacent to AOC E. The Vieques Passage is located approximately 850 feet (ft) north of the site.

Currently, there is no continuous human presence or use at the site, but Publics Works personnel may periodically be present for routine grounds maintenance (e.g., mowing). The area that includes the sites is fenced to discourage trespassing. Because of the developed and periodically maintained conditions of AOC E, ecological habitat in the area is minimal. Vegetative cover is primarily grass, weeds, and scrub brush. No endangered or threatened species were observed at AOC E, nor are any expected to use the site as habitat. No cultural resources are located at AOC E.

SAP Worksheet #10a — AOC E Problem Definition (continued)

Site Geology

The soil at the site comprises sandy clay of the Qa geologic unit (Quaternary or Holocene alluvium) with interspersed silty/clayey sand from ground surface to a depth of approximately 35 feet below ground surface (bgs) in the vicinity of the former UST. Beneath these deposits lies a clay-rich saprolite weathered in place from the underlying granodiorite bedrock. The sandy clay and silty/clayey sand layers are generally above the water table, though the lowest sections are submerged at the site's highest recorded water levels. The top of the saprolite varies in elevation from approximately 28 feet bgs to below 50 feet bgs. Figure 3 shows a geologic cross section.

Site Hydrogeology

Depth to groundwater typically ranges from approximately 28 to 43 feet bgs, with seasonal (or drought-induced) fluctuations up to approximately 15 feet. Groundwater is usually encountered in the saprolite, but sometimes in the lowest portion of the unconsolidated, sandy deposits directly above the saprolite. The direction of groundwater flow is to the north-northwest toward the Vieques Passage. Slug-test data for several onsite monitoring wells in combination with hydraulic gradient data and formation effective porosity suggest a relatively low groundwater velocity (about 1 foot/year). While slug test data in saprolite are prone to a high degree of uncertainty, the general absence of contamination in wells located as little as about 50 feet downgradient of the former UST supports this velocity estimate.

In general, the shallow soil (<16 to 18 feet bgs) in the area contains a high clay content and exhibits a low hydraulic permeability (10^{-7} cm/s). The clay content decreases and the hydraulic permeability increases with depth. The highest hydraulic permeability in the unsaturated zone soil is approximately 10^{-3} cm/s.

The saturated unconsolidated material in the proposed pilot AOC E study area is clay-rich and has low permeability, as evidenced by the hydraulic conductivity measured in 2002 (Appendix F; CH2M HILL, 2008a). The conductivity in monitoring well MW-04 was 0.2 feet per day, (7.06×10^{-5} centimeters per second [cm/sec]).

Conceptual Site Model

The CSM of AOC E is presented in Figure 4, which shows the historical features and estimated contamination migration route and extent. Based on the historical activities and extent of contamination identified during the RI and related investigations, the release mechanism at the site is believed to have been subsurface leaks from the former UST and associated piping. Therefore, the primary route of contaminant migration is likely vertical leaching through soil to groundwater and subsequent transport with groundwater flow through interstitial spaces in the saprolite (and to a lesser extent, the unconsolidated material overlying the saprolite). Because the saprolite consists of relatively "tight" clay and the hydraulic gradient across the site is low, the rate of groundwater transport is likely very low. This supposition is supported by the general absence of contamination downgradient of the former UST area and relatively low estimated groundwater flow velocity. Because of the nature of the released materials (i.e., used engine oils), residual petroleum hydrocarbon contamination is present in the soil between the base of the former UST/associated piping excavation and the saturated zone, primarily at the depths between 16 ft bgs 38 ft bgs according to the data from the subsurface soil sampling conducted in July 2008 (CH2M HILL, 2008b).

SAP Worksheet #10a — AOC E Problem Definition (continued)

Additionally, because of floating product observed on the water table in the past, the fluctuation of the groundwater surface has likely created a "smear zone" of contamination within the vertical extent of fluctuation.

Summary of Baseline HHRA and ERA

A baseline HHRA contained in the *Final Remedial Investigation Report* (CH2M HILL, 2008a) identified five groundwater COCs. Based on groundwater datasets collected during May 2002 and August/September 2004 events, the COCs comprise 1,2-dichloroethane (1,2-DCA), 2-methylnaphthalene, MTBE, naphthalene, and xylenes. Additional groundwater samples collected and analyzed in July 2008 indicated the COC concentrations had generally declined (Exhibit 2, *Technical Memorandum – Proposed Pilot Study of In-Situ Remediation at Vieques AOC E*, CH2M HILL, 2008b). Only benzene, naphthalene, and MTBE exceeded the pilot study PRGs in July 2008, as discussed below.

The HHRA also evaluated the soil data collected during the 2002 RI and the 2005 Supplemental RI (CH2M HILL, 2008a). The potential risks based on the direct contact exposure pathways to COCs detected in soil were within the U.S. Environmental Protection Agency (EPA) acceptable range and were therefore not a remedial action driver (from a risk standpoint).

As summarized above, although contaminants are present in both soil and groundwater at the site, only the groundwater contamination poses an unacceptable risk (under the potable use scenario) to hypothetical future residents. However, soil contamination between the bottom of the former UST/associated piping and the saturated zone may act as a continuing source of groundwater contamination. Sampling in July 2008 indicated that naphthalene is the only groundwater COC whose concentration in soil may leach from unsaturated soil into groundwater and result in a groundwater concentration exceeding the conservative pilot study PRG of 1.4 µg/L.

Based on the ERA, no unacceptable risks were identified for ecological receptors at AOC E (CH2M HILL, 2008a).

Pilot Study PRGs

Although several of the COCs identified in the RI Report appear to have declined to below risk-based or MCL criteria, due to the potential for seasonal or other temporal variations and fluctuations in groundwater concentrations, all of the COCs identified in the HHRA plus benzene (exceedance of MCL observed in July 2008) will be analyzed during the pilot study. As summarized in the evaluation of historic data and data collected in July 2008 in the Technical Memorandum *Proposed Pilot Study of In-Situ Remediation at Vieques AOC E* (CH2M HILL, 2008b), the following "Pilot Study PRGs" were developed, based on the EPA MCLs, or the September 2008 EPA Regional Screening Levels (RSLs) for constituents without MCLs.

SAP Worksheet #10a — AOC E Problem Definition (continued)

COCs	Pilot Study PRGs	Source of PRGs
Benzene	5 µg/L	MCL
1,2-dichloroethane	5 µg/L	MCL
2-methylnaphthalene	150 µg/L	Hazard Index (HI) of 1 based on the September 2008 EPA Regional Screening Level
MTBE	120 µg/L	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level
Naphthalene	1.4 µg/L*	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level
Total xylenes	10,000 µg/L	MCL

* Note: A pilot study PRG of 1.4 µg/L was selected solely to represent a conservative screening value to evaluate the technical implementability and effectiveness of the proposed pilot study technology. The EPA's health-advisory life-time value for naphthalene is 100 µg/L (USEPA, 2006), which would most likely be the final clean-up level in groundwater for naphthalene.

Pilot Study Objectives

The pilot study will be conducted to evaluate the implementability and effectiveness of the proposed denitrification-based bioremediation (DBB) for unsaturated zone soil remediation, and proposed in-situ chemical oxidation (ISCO) and enhanced in-situ bioremediation (EISB) for groundwater remediation at AOC E. The potential to reduce the cleanup timeframe will also be evaluated. The specific objectives of the pilot study are summarized below.

<u>DBB Pilot Study</u>

- To evaluate whether the pilot study technology can reduce the mass of petroleum hydrocarbon (primarily naphthalene) in the unsaturated zone and smear zone soil
- To evaluate whether the pilot study technology can reduce the potential of soil to groundwater leaching of COCs

<u>ISCO and EISB Pilot Study</u>

- To evaluate whether the pilot study technology can reduce the time required to reach the Pilot Study PRGs
- To evaluate whether the pilot study technology can reduce the COC concentrations in groundwater below the Pilot Study PRGs

Pilot Study Approach

The proposed pilot study approach consists of two components: (1) treatment of the unsaturated zone soil using DBB and (2) remediation of the groundwater using ISCO injection of activated persulfate followed by EISB with placement of ORC socks. The project tasks associated with the pilot study are detailed in Worksheet 14a. Evaluation of the data and selection of appropriate pilot study technologies are provided in the Technical Memorandum *Proposed Pilot Study of In-Situ Remediation at Vieques, AOC E* (CH2M HILL, 2008b), which is included as Attachment B to this SAP. MSDSs of the proposed products (sodium hydroxide, sodium persulfate, and ORC) are included in Attachment G. It is important to note that there are several deviations in the pilot study approach presented in this SAP versus the Technical Memorandum. This is because the Technical Memorandum is conceptual in nature, whereas the approach presented in this SAP was developed using a systematic process and, therefore, supersedes the Technical Memorandum approach.

SAP Worksheet #10a — AOC E Problem Definition (continued)

Synopsis of Secondary Data

Secondary data have been collected during a series of historical site investigations. Information on the limitations of the secondary data can be found in Worksheet #13. A chronological list of key site documents and site investigation activities to date is summarized below:

- CH2M HILL conducted the Site Characterization in August and September 1998, including collecting 8 subsurface soil samples and installing and sampling 3 monitoring wells (MW-01 through MW-03) (CH2M HILL, 1999).
- CH2M HILL conducted an Expanded PA/SI at AOC E in April and May 2000, including installing and sampling 3 monitoring wells (MW-04 through MW-06), sampling 2 existing monitoring wells (MW-02 and MW-03), and measuring free product thickness (approximately 0.1 ft) in MW-01 (CH2M HILL, 2000).
- CH2M HILL conducted initial Remedial Investigation (RI) sampling from May through August 2002 and September 2003, including collecting 20 soil samples from 7 soil borings, installing and sampling 2 monitoring wells (MW-07 and MW-08), sampling 4 existing monitoring wells, measuring free product thickness in MW-01 (approximately 0.42 ft) and MW-05 (approximately 0.28 ft), and performing slug tests in 2 wells (CH2M HILL, 2004).
- CH2M HILL performed a 10-week multiphase extraction (MPE) pilot test in monitoring wells MW-01 and MW-05 from June 2002 to August 2002, to recover free product, groundwater, and soil vapors (Appendix H, CH2M HILL, 2008a).
- CH2M HILL conducted the supplemental RI sampling from August 2004 to December 2005, including collecting two rounds of groundwater samples from all monitoring wells with the absence of free product, and collecting surface soil samples from 7 locations and subsurface soil samples from 4 locations. The sampling results, detailed nature and extent of contamination, and a conceptual site model were documented in the Final RI Report dated July 2008 (CH2M HILL, 2008a).
- CH2M HILL performed an additional round of soil and groundwater sampling in July 2008, including collection of 2 surface soil samples and 13 subsurface soil samples from 2 soil borings (SB-20 and SB-21), and collection of groundwater samples from all 8 monitoring wells. No free product was detected in any monitoring wells. The soil data collected in July 2008 will be used as the baseline (pre-injection) data to evaluate the performance of the pilot study. Because natural attenuation likely continues to decrease the COC concentrations in soil (at a slow rate) between the July 2008 event and the pilot study (estimated to be approximately January 2010), the effect of DBB in decreasing the COC concentrations may be overestimated. The total decrease in COC concentrations will likely be partially attributable to natural attenuation. Additional groundwater data will be collected pre-injection to use as the baseline data to evaluate the performance of the pilot study.
- A technical memorandum documenting the conceptual approach for the proposed in-situ remediation pilot study was prepared in December 2008 (CH2M HILL, 2008b) and is included as Attachment B.

SAP Worksheet #10a — AOC E Problem Definition (continued)

Problem Definition

Although impacted soil and groundwater are localized in a relatively small area and exhibit low concentrations of contaminants (relative to MCL- or risk-based levels), natural attenuation modeling of the current contaminant concentrations suggests 10 to 20 years may be required for the contaminants to meet the Pilot Study PRGs (CH2M HILL, 2008b). The Navy no longer owns nor is present at AOC E and therefore institutional controls would be required as the contaminant concentrations attenuate to acceptable levels. The Navy and Municipality of Vieques (MOV) would likely benefit from being able to return the site unencumbered (i.e., without restrictions) to the MOV in a shorter timeframe. In addition, while several remediation technologies are potentially able to reduce high concentrations of contaminants to lower concentrations, few potentially can reduce already low concentrations (such as those observed at AOC E) to even lower concentrations to meet PRGs. A pilot study at AOC E would help assess the implementability and effectiveness of in-situ remediation in reducing the target COC concentrations in groundwater below the Pilot Study PRGs and reducing the potential of soil to groundwater leaching.

For the ISCO portion of the pilot study, the Navy will use existing monitoring wells as injection points. The area of contamination is so small that if injection points were installed, they would be within several feet of the existing monitoring wells, so the concerns of oxidant sampling discussed below would still apply. If the monitoring wells were to be sampled within several weeks after being used as injection points, it is possible that the groundwater samples collected would contain the oxidant due to the water displacement that occurs during injection. Several steps outlined in the environmental questions below will be taken to mitigate this and ensure performance monitoring is based on groundwater samples representative of the aquifer.

Environmental Questions to be Answered by the Pilot Study:

1. **Is DBB an appropriate remedial technology for reducing the groundwater COCs (primarily naphthalene) in soil to concentrations that do not pose a soil-to-groundwater leaching concern?**

   Nitrate will be delivered to the unsaturated zone soil as electron acceptor to enhance the aerobic biodegradation rate and achieve concentration reduction of naphthalene and other petroleum hydrocarbons, reducing the potential of soil to groundwater leaching. The injection depth intervals will be 16 to 26 ft bgs, and the nitrate is anticipated to migrate vertically through the unsaturated zone and smear zone soil via infiltration. A temporal increase of nitrate concentration in the smear zone and/or groundwater might be observed for several months, but with continued biodegradation, nitrate concentrations will decrease.

   The soil boring sampling results collected in July 2008 will serve as baseline data (pre-injection). In July 2008, two continuous soil cores (SB-20 beneath the former UST and SB-21 beneath the former piping) were drilled. A total of 13 soil samples were collected between 8 and 38 ft bgs with 3-inch-diameter split spoons and Shelby Tubes. Results indicated that impacted soil was primarily at the following depths: 16-18, 18-20, 28-30, 34-36, and 36-38 ft bgs, with total VOC concentrations up to approximately 93 mg/kg, and total SVOC concentrations up to 34 mg/kg.

SAP Worksheet #10a — AOC E Problem Definition (continued)

In order to evaluate the concentration reduction, post-nitrate injection soil sampling will be conducted, which will occur approximately during month 26 or month 28, depending on whether a third ISCO injection is needed (see Worksheet 16a-1 for a 2 ISCO injection scenario and 16a-2 for a contingency 3 ISCO injection scenario). The exact timing of the post-nitrate injection soil sampling is not critical; therefore, it is timed to coincide with the final groundwater sampling event for efficiency.

A total of five split spoon soil samples will be collected from two soil borings (SB-22 and SB-23; see Figure 5) in general accordance with *Master Standard Operating Procedures, Protocols, and Plans* (CH2M HILL, July 2009). Two soil samples from each boring will be collected from the highest COC concentration depth intervals observed in July 2008 event for laboratory analysis: one from the unsaturated zone where injection occurred (16-20 ft bgs), and one from the smear zone below the injection interval (28-32 ft bgs). In addition, one field duplicate sample will be collected from one soil sampling depth in one soil boring. This equates to five total soil samples collected from the two soil boring locations. The samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2).

The samples will be analyzed for VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLP VOCs and SVOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH (ranges GRO, DRO, and ORO), TOC, pH, and nitrate. The VOCs and SVOCs are the site-specific COCs in groundwater identified in the HHRA. Considering the heterogeneity of subsurface conditions and groundwater has already been affected by target COCs, the groundwater COCs identified in the baseline HHRA, comprising 1,2-DCA, 2-methylnaphthalene, MTBE, naphthalene, and xylenes, as well as benzene (due to groundwater MCL exceedance), are included in the post-nitrate injection unsaturated soil sampling. VOC and SVOC soil concentration data will be compared against baseline soil sampling data collected in July 2008 to evaluate the percent concentration reduction. Although a reduction in MTBE may not be observable in soil because the laboratory QL (5 μg/kg) and MDL (0.75 μg/kg) are above the maximum concentration observed in July 2008 (0.3 μg/kg), the concentration observed in 2008 was already less than the Regional Screening Level for leaching to groundwater (2.7 μg/kg). SPLP sampling results will be compared to the project action levels (i.e., pilot study PRGs for groundwater adjusted by dilution factor; see Worksheet 11) to determine whether the post-injection concentrations of these COCs could continue to contribute to soil-to-groundwater leaching at levels that would result in unacceptable groundwater concentrations (i.e., above MCLs or risk-based levels).

2. **<u>Are ISCO and EISB appropriate remedial technologies for reducing the groundwater COCs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene, and naphthalene) to concentrations at or below the Pilot Study PRGs?</u>**

   Persulfate is an aggressive oxidizing agent for remediation of petroleum hydrocarbons. Persulfate (oxidation potential of 2.01 volts) is a slightly stronger oxidant than MnO_4^- (oxidation potential of 1.7 volts). However, when catalyzed, persulfate ($S_2O_8^{2-}$) will degrade to form the sulfate radicals with a higher oxidation potential: 2.6 volts (Interstate Technology & Regulatory

SAP Worksheet #10a — AOC E Problem Definition (continued)

Council [ITRC], 2005). Persulfate is generally considered to be less sensitive to soil organic matter, resulting in lower soil oxidant demands (SOD), and can be persistent in the subsurface for several weeks (typically 3 to 6 weeks). The networks of proposed ISCO and EISB treatment wells are shown in Figure 6. The pre-injection concentrations of COCs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene) and TPH (ranges

GRO, DRO, and ORO) collected during month 1 will be used as the baseline data. Pre-injection water quality field parameters (pH, temperature, specific conductivity, ORP, turbidity, DO), sulfate, and persulfate will also be collected. Performance sampling data will be collected from monitoring wells in accordance with the sampling schedule in worksheets 16a-1 and 16a-2 (contingency) to evaluate the concentration reduction of the COCs. The post-ISCO injection groundwater sampling events are scheduled to allow the oxidant to be consumed (up to 6 weeks) and a level of equilibrium in the subsurface to occur (i.e., 7 months after final ISCO injection). The post-EISB treatment (i.e., placement of ORC socks) groundwater samples will be collected 2 to 3 months after the removal of the ORC socks, again to allow the aquifer to achieve equilibrium prior to sampling.

Although it is unlikely that NAPL exists at AOC E due to the historical NAPL recovery during a pilot MPE program and from the last three years of NAPL thickness measurements, if a sheen is observed, the ISCO injections will likely oxidized it. If recoverable NAPL is observed, hand bailer will be used to remove any recoverable NAPL, then the necessity of using another round of ISCO to remove residual NAPL will be evaluated at that time.

3. **What are the threshold COC concentrations in groundwater that will trigger a third ISCO injection prior to EISB treatment?**

   The Technical Memorandum (CH2M HILL, 2008b) proposed triggers for the contingency plan (consisting of implementing a third ISCO injection) that are a COC's concentration in any of the monitoring wells greater than 35 percent of the COC's Pilot Study PRG. However, given the relatively wide range of pilot study PRGs for different COCs and very low concentrations for several COCs, the proposed triggers for the contingency plan (consisting of implementing a third ISCO injection) are COC concentrations in any one of the monitoring wells greater than the threshold concentrations (see table below). The threshold concentrations are based on estimate for the remaining concentrations to be likely aerobically degraded below the pilot study PRGs within 1 year by EISB. Analytical results from the groundwater sampling event 7 months after the second injection will be used to make the determination if a third ISCO treatment is needed by comparing these analytical results to the threshold COC concentrations.

COCs	Pilot Study PRGs	Third ISCO Injection Threshold COC Concentrations
Benzene	5 µg/L	> 10 µg/L
1,2-dichloroethane	5 µg/L	> 8 µg/L
2-methylnaphthalene	150 µg/L	> 200 µg/L
MTBE	120 µg/L	> 150 µg/L
Naphthalene	1.4 µg/L	> 5 µg/L
Total xylenes	10,000 µg/L	> 12,000 µg/L

SAP Worksheet #10a — AOC E Problem Definition (continued)

4. **How will monitoring data be collected and evaluated to ensure they are representative of the aquifer conditions, not of the injected material?**

   Given that persulfate persistence in the groundwater typically ranges from 3 to 6 weeks, the pilot study sampling interval (7 month period following the last round of ISCO injection) is sufficient to ensure the monitoring data being collected in wells are representative of the aquifer conditions. In addition, field testing for persulfate concentrations prior to sampling will be performed, to ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate). Furthermore, typical ISCO field applications target a pore volume of 20 to 50 percent, whereas the design for AOC E targets injecting a solution between 10 and 20 percent of the pore volume around an injection point. In addition, in order to optimize contact and/or mixing between the oxidant and both adsorbed and dissolved COCs while minimizing the water displacement, gravity feeding (using the hydraulic head from the water table to the ground surface) will be initially tested to deliver the oxidant to the aquifer; however, if the injection rate in the field is below 0.5 gpm (due to low hydraulic conductivity), then low pressure injection (up to 30 psi) will be tested in order to deliver the oxidant mass to the subsurface in a cost-effective and time-efficient manner. Water quality parameters will be closely monitored when collecting performance monitoring groundwater samples to ensure that these are stable and reflect expected groundwater conditions. The ORP, DO, and conductivity may be higher than background conditions due to the desired effects of the oxidant. After the EISB treatment (i.e., removal of ORC socks from the treatment wells), a two-month interval will ensure well equilibration has been achieved prior to sampling.

5. **Is application of ISCO and EISB likely to reduce the overall cleanup time?**

   Trend curves depicting COC concentrations versus time will be produced from the site data prior to and following implementation of ISCO and EISB. These graphs will be evaluated for first order degradation/destruction rates to help assess the degree of reduced time (relative to the baseline established in the pilot study memorandum) for reaching cleanup criteria.

SAP Worksheet #10b — AOC I Problem Definition

Introduction

This worksheet provides a summary of site background and key elements of the CSM, followed by a narrative description of the problems to be addressed during the proposed pilot study.

The proposed pilot study activities include performing one round of ISCO injection and EISB via existing wells for groundwater remediation, and collecting pre- and post-injection groundwater samples. Because the groundwater COC concentrations are slightly above the Pilot Study PRGs, it is believed that one ISCO application followed by EISB treatment with the placement of ORC socks will achieve the pilot study objective. CH2M HILL will perform these activities to evaluate the effectiveness of the pilot study in meeting the proposed pilot study PRGs that are discussed herein.

Background

This section provides a summary of site background, key elements of the CSM (including the site setting and history, geology, hydrogeology), summary of baseline HHRA and ERA, pilot study PRGs, pilot study objective, and the pilot study approach. Detailed information about the site's characteristics can be found in the Remedial Investigation (RI) Report for AOC I (CH2M HILL, 2008c).

Site Setting and History

AOC I, a former asphalt plant, is located approximately 900 feet (ft) south of Mosquito Pier, adjacent to an active Public Works Department rock quarry on the western side of Vieques, Puerto Rico. The location of AOC I, within the former NASD, is presented in Figure 7. The asphalt plant was in operation from the 1960s through 1988. The former asphalt plant comprised one large concrete pad containing the asphalt mixing drum, one earthen ramp with a sheet metal support wall, one concrete-paved containment area, and an area where two diesel fuel above-ground storage tanks (ASTs) were formerly located. An additional concrete containment area is located approximately 50 ft north of the former plant. Both the containment areas have sumps. Figure 8 shows the site map, including site features and locations of monitoring wells.

The AOC I area occupies approximately 1 acre, but the asphalt plant itself occupied a considerably smaller area. The topography of the site is relatively flat; stormwater at and in the immediate vicinity of the former asphalt plant was observed to pond at the site during a rain event rather than run off. At the northern, eastern, and southern margins of the site, the topography slopes downward to Route 200 (to the north), the quarry (to the south), and a drainage ditch for the quarry (to the east).

Currently, there is no continuous human presence or use of the site other than potentially as a passageway for trucks to/from the rock quarry from Route 200. The area that includes the site is fenced to discourage trespassing. Ecological habitat at the former asphalt plant is minimal, consisting primarily of scrub grass, brush, and small trees growing in and around

SAP Worksheet #10b — AOC I Problem Definition (continued)

the former asphalt plant structures and through the gravel-covered terrain. No federally-protected species or preferred habitats were observed at AOC I, nor are any cultural resources present at the site.

Site Geology

The surficial material at the site is comprised of gravel fill interspersed with silty clay and sand. Beneath the thin veneer of fill, the soil zone at the site is relatively thin (generally 2 to 9 ft thick) and consists of well-graded gravel with sand of the Qa geologic unit (Quaternary or Holocene alluvium). Andesite bedrock lies below the soil, often weathered at its surface to a saprolite. Figure 9 shows the geologic cross section.

Site Hydrogeology

The upper portion of the bedrock is unsaturated. Depth to groundwater typically ranges from 17 to 25 feet below ground surface (bgs), with seasonal fluctuation up to approximately 5 feet. Lateral groundwater flow in andesite bedrock is complex because it is confined to fractures within the bedrock. The directions and rates of groundwater movement in bedrock are confined by the size, frequency, and orientation of fractures and by the hydraulic gradient and, therefore, can be quite variable on the small-scale. However, the general direction of groundwater flow at AOC I for all three rounds of water level measurements is northwest toward the Vieques Passage. The hydraulic conductivity measured in 2004 and 2006 in monitoring wells ranged from 0.1 foot per day to 8.6 feet per day. The northern portion well MW-06 has the lowest hydraulic conductivity of 0.1 ft per day, while average hydraulic conductivity in southern and central wells (MW01 through MW-05) is 4.1 ft/day. Based on the water levels from the March 2006 measurement, the horizontal hydraulic gradient in the southern and central portion of AOC I was approximately 0.0043 feet per foot (ft/ft), but increased to approximately 0.033 ft/ft in the northern portion of AOC I (CH2M HILL, 2008c). The measured hydraulic conductivities in on-site monitoring wells in combination with hydraulic gradient data and formation effective porosity suggest a relatively low groundwater velocity ranging from 3 to 16 ft per year, with higher seepage velocity observed in the southern and central portion of the AOC I.

Conceptual Site Model

The CSM of AOC I is presented in Figure 10, which shows the historical features and estimated contamination migration route and extent. Based on the historical activities and extent of contamination identified during the RI and related investigation, CERCLA-related releases occurred during past asphalt plant operations, likely in the form of minor drips and spills. The primary route of contaminant migration is likely vertical leaching through soil and bedrock to groundwater and subsequent transport with groundwater flow through fractures in the bedrock aquifer. However, the extent of contamination is generally limited to the immediate vicinity of the former asphalt plant. Further, the contaminant levels present in environmental media are relatively low with respect to human health-based and ecological-based screening values. Potable groundwater use by residents is the only unacceptable risk identified for the site, as summarized below.

SAP Worksheet #10b — AOC I Problem Definition (continued)

Summary of Baseline HHRA and ERA

A baseline HHRA identified six groundwater COCs comprising benzene, bis(2-ethylhexyl)phthalate, 1,2-dichloroethane, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene (CH2M HILL, 2008d). No COCs were identified in soil because the potential risks associated with the chemical constituents detected in soil are acceptable. The concentrations of the six groundwater COCs in soil are also lower than the concentrations that would likely need to be present to pose a leaching-to-groundwater concern.

Additional groundwater samples collected and analyzed in July 2008 indicated that only benzene and naphthalene exceeded the pilot study PRGs, and in only one monitoring well (MW-07). Benzene and naphthalene concentrations in MW-07 were measured in July 2008 at concentrations of 24 and 35 µg/L, respectively.

Based on the ERA, no unacceptable risks were identified for ecological receptors at AOC I (CH2M HILL, 2008d).

Pilot Study PRGs

Although several of the COCs identified in the RI Report appear to have declined to below risk-based or MCL criteria, due to the potential for seasonal or other temporal variations and fluctuations in groundwater concentrations, all of the COCs identified in the RI Report will be analyzed during the pilot study. As summarized in the evaluation of historic data and data collected in July 2008 in the Technical Memorandum *Proposed Pilot Study of In-Situ Remediation at Vieques AOC I* (CH2M HILL, 2008c), the following "Pilot Study PRGs" were developed, based upon the EPA MCLs, or the September 2008 EPA RSLs for constituents without MCLs.

COCs	Pilot Study PRGs	Source of PRGs
Benzene	5 µg/L	MCL
Bis (2-ethylhexyl) phthalate	6 µg/L	MCL
1,2-Dichloroethane	5 µg/L	MCL
1,2-Dichloropropane	5 µg/L	MCL
2-Methylnaphthalene	150 µg/L	Hazard Index (HI) of 1 based on the September 2008 EPA Regional Screening Level
Naphthalene	1.4 µg/L*	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level

* Note: A pilot study PRG of 1.4 µg/L was selected solely to represent a conservative screening value to evaluate the technical implementability and effectiveness of the proposed pilot study technology. The EPA's health-advisory life-time value for naphthalene is 100 µg/L (USEPA, 2006), which would most likely be the final clean-up level in groundwater for naphthalene.

Pilot Study Objective

The pilot study will be conducted to evaluate the implementability and effectiveness of the proposed ISCO and EISB for groundwater remediation at AOC I. The potential to reduce the cleanup timeframe will also be evaluated. The specific objectives of the pilot study are summarized below.

SAP Worksheet #10b — AOC I Problem Definition (continued)

ISCO and EISB Pilot Study

- To evaluate whether the pilot study technology can reduce the time required to reach the Pilot Study PRGs
- To evaluate whether the pilot study technology can reduce the COC concentrations in groundwater below the Pilot Study PRGs

Pilot Study Approach

The proposed pilot-study approach consists of an ISCO injection of activated persulfate followed by EISB with placement of ORC socks. The project tasks associated with the pilot study are detailed in Worksheet 14b. Evaluation of the data and selection of appropriate pilot study technologies are provided in the Technical Memorandum *Proposed Pilot Study of In-Situ Remediation at Vieques, AOC I* (CH2M HILL, 2008d), which is included as Attachment C to this SAP. It is important to note that there are several deviations in the pilot study approach presented in this SAP versus the Technical Memorandum. This is because the Technical Memorandum is conceptual in nature, whereas the approach presented in this SAP was developed using a systematic process and, therefore, supersedes the Technical Memorandum approach.

Synopsis of Secondary Data

Secondary data have been collected during a series of historical site investigations. Information on the limitations of the secondary data can be found in Worksheet #13. A chronological list of key site documents and site investigation activities to date is summarized below:

- ERM conducted an Environmental Baseline Survey (EBS) in March 2000, and collected 3 surface soil samples (i.e., one each adjacent to areas where black staining was observed on the concrete surfaces of the two containment areas and one from stained soil at the location of the former diesel fuel ASTs) (Program Management Company, 2000).
- CH2M HILL conducted an Expanded PA/SI at AOC I in November and December 2000, including an ecological survey and collection of 26 co-located surface soil samples (0 to 0.5 ft bgs) and subsurface soil samples (4 to 6 ft bgs) (CH2M HILL, 2002).
- CH2M HILL conducted initial RI from August through September 2004, including surface soil sampling at 18 locations, subsurface soil sampling at 7 locations, and installing and sampling 7 monitoring wells (CH2M HILL, 2005).
- CH2M HILL conducted a supplemental RI from November 2005 to January 2006, including installation of 2 monitoring wells and sampling 9 wells. The sampling results were documented in the Final RI Report dated June 2008 (CH2M HILL, 2008d).
- CH2M HILL performed an additional round of groundwater sampling in July 2008, including collection of groundwater samples from all 9 monitoring wells. Additional groundwater data will be collected pre-injection to use as the baseline data to evaluate the performance of the pilot study.

SAP Worksheet #10b — AOC I Problem Definition (continued)

- A technical memorandum documenting the conceptual approach for the proposed in-situ remediation pilot study was prepared in November 2008 (CH2M HILL, 2008c) and is included as Attachment C.

Problem Definition

Although impacted groundwater is localized in a relatively small area with low concentrations of contaminants (relative to MCL- or risk-based levels), natural attenuation modeling of the current contaminant concentrations suggests 7 to 14 years may be required for the contaminants to meet the Pilot Study PRGs (CH2M HILL, 2008c). The Navy no longer owns nor is present at AOC I and therefore institutional controls would be required as the contaminant concentrations attenuate to acceptable levels. Therefore, the Navy and the MOV would likely benefit from being able to return the site unencumbered (i.e., without restrictions) to the MOV in a shorter timeframe. In addition, while several remediation technologies are potentially able to reduce high concentrations of contaminants to lower concentrations, few potentially can reduce already low concentrations (such as those observed at AOC I) to even lower concentrations to meet PRGs. A pilot study at AOC I would help assess the implementability and effectiveness of in-situ remediation in reducing the target COC concentrations in groundwater below the Pilot Study PRGs.

For the ISCO portion of the pilot study, the Navy will use existing monitoring wells as injection points. The area of contamination is so small that if injection points were installed, they would be within several feet of the existing monitoring wells, so the concerns of oxidant sampling discussed below would still apply. If the monitoring wells were to be sampled within several weeks after being used as injection points, it is possible that the groundwater samples collected would contain the oxidant due to the water displacement that occurs during injection. Several steps outlined in the environmental questions below will be taken to mitigate this and ensure performance monitoring is based on groundwater samples representative of the aquifer.

Environmental Questions to be Answered by the Pilot study:

6. **Are ISCO and EISB appropriate remedial technologies for reducing the groundwater COCs (benzene, bis(2-ethylhexyl)phthalate, 1,2-dichloroethane, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene) to concentrations at or below the Pilot Study PRGs?**

   Persulfate is an aggressive oxidizing agent for remediation of petroleum hydrocarbons. Persulfate (oxidation potential of 2.01 volts) is a slightly stronger oxidant than MnO_4^- (oxidation potential of 1.7 volts). However, when catalyzed, persulfate ($S_2O_8^{2-}$) will degrade to form the sulfate radicals with a higher oxidation potential: 2.6 volts (Interstate Technology & Regulatory Council [ITRC], 2005). Persulfate is generally considered to be less sensitive to soil organic matter, resulting in lower soil oxidant demands (SOD), and can be persistent in the subsurface for several weeks (typically 3 to 6 weeks). One round of pre-injection groundwater samples will be collected as the baseline for evaluation of pilot study performance. Pre-injection water quality field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), sulfate, and persulfate will also be collected. Performance sampling data will be collected from monitoring wells in accordance with the sampling schedule in worksheets 16b to evaluate the concentration reduction of site-specific COCs. The post-ISCO injection groundwater sampling events are scheduled to allow the oxidant to be consumed (up to 6 weeks) and a level of

SAP Worksheet #10b — AOC I Problem Definition (continued)

equilibrium in the subsurface to occur (i.e., 3 months after the ISCO injection). The post-EISB treatment (i.e., placement of ORC socks) groundwater samples will be collected 2 to 3 months after the removal of the ORC socks, again to allow the aquifer to achieve equilibrium prior to sampling.

7. **How will monitoring data be collected and evaluated to ensure they are representative of the aquifer conditions, not of the injected material?**

   In order to take advantage of the same mobilization of groundwater sampling at AOC E, the first post-ISCO injection groundwater sampling event at AOC I will occur at Month 4, approximately 3 months after the ISCO injection (See Worksheet 16b). The 3 month interval at AOC I is less than the 7 month interval at AOC E. However, given that persulfate persistence in the groundwater typically ranges from 3 to 6 weeks, the pilot study sampling interval (3 month period following the ISCO injection) is sufficient to ensure the monitoring data being collected in wells are representative of the aquifer conditions. Given the relatively low COC concentrations in the groundwater, it is believed that one ISCO injection is sufficient to reduce the COC concentrations below PRGs. In addition, field testing for persulfate concentrations prior to sampling will be performed, to ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate). Furthermore, typical ISCO field applications target a pore volume of 20 to 50 percent, whereas the design for AOC I targets injecting a solution that is between 10 and 20 percent of the pore volume around an injection point. In addition, in order to optimize contact and/or mixing between the oxidant and both adsorbed and dissolved COCs while minimizing the water displacement, gravity feeding (using the hydraulic head from the water table to the ground surface) initially tested to deliver the oxidant to the aquifer; however, if the injection rate in the field is below 0.5 gpm (due to low hydraulic conductivity), then low pressure injection (up to 30 psi) will be tested in order to deliver the oxidant mass to the subsurface in a cost-effective and time-efficient manner. Water quality parameters will be closely monitored when collecting performance monitoring groundwater samples to ensure that these are stable and reflect expected groundwater conditions. The ORP, DO, and conductivity may be higher than background conditions due to the desired effects of the oxidant. After the EISB treatment (i.e., removal of ORC socks from the treatment wells), a two-month interval will ensure that well equilibration has been achieved prior to sampling.

8. **Is application of ISCO and EISB likely to reduce the overall cleanup time?**

   Trend curves depicting COC concentrations versus time will be produced from the site data prior to and following implementation of ISCO and EISB. These graphs will be evaluated for first order degradation/destruction rates to help assess the degree of reduced time (relative to the baseline established in the pilot study memorandum) for reaching cleanup criteria.

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SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements

1. Who will use the data and what will the data be used for?

Since the primary objective of the pilot studies is to assess the effectiveness of in-situ remediation techniques, the Navy, USEPA, and EQB will use the data collected during the pilot studies to determine whether the technologies can 1) reduce groundwater COCs at AOCs E and I to concentrations at or below the Pilot Study PRGs (i.e., MCL- or risk-based levels), 2) reduce groundwater COCs in soil at AOC E to concentrations that do not represent soil-to-groundwater leaching concerns, and 3) reduce the cleanup timeframe. Based on the results of the pilot studies, the Navy, USEPA, and EQB will make a decision whether no further action, a feasibility study (FS), or another path forward is warranted.

2. What are the Project Action Limits (PALs)?

The RI, including the baseline HHRA, identified several COCs (see below) in groundwater contributing to unacceptable human health risks or MCL exceedances. Therefore, the PALs for the groundwater COCs are the pilot study PRGs, as presented in Technical Memoranda (CH2M HILL, 2008b and 2008c) and summarized below:

TABLE 1
Groundwater PALS For AOC E and AOC I

COCs	Groundwater PALs (Pilot Study PRGs)	Site	Source of PALs
Benzene	5 µg/L	AOC E and AOC I	MCL
1,2-Dichloroethane	5 µg/L	AOC E and AOC I	MCL
1,2-Dichloropropane	5 µg/L	AOC I	MCL
2-Methylnaphthalene	150 µg/L	AOC E and AOC I	Hazard Index (HI) of 1 based on the September 2008 EPA Regional Screening Level (RSL)
MTBE	120 µg/L	AOC E	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level (RSL)
Bis (2-ethylhexyl) phthalate	6 µg/L	AOC I	MCL
Naphthalene	1.4 µg/L*	AOC E and AOC I	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level (RSL)
Xylenes, total	10,000 µg/L	AOC E	MCL

* Note: A pilot study PRG of 1.4 µg/L was selected solely to represent a conservative screening value to evaluate the technical implementability and effectiveness of the proposed pilot study technology. The EPA's health-advisory life-time value for naphthalene is 100 µg/L (USEPA, 2006), which would most likely be the final clean-up level in groundwater for naphthalene.

SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements (continued)

Soil PALs (in terms of SPLP units of µg/L) are only applicable to AOC E because of the soil-to-groundwater leaching concern of naphthalene (CH2M HILL, 2008a and 2008b). SPLP sampling results for other COCs were either non-detect or far below the MCLs or RSL in groundwater. This is likely attributable to the more mobile features of other COCs and releases that occurred over 13 years ago. Naphthalene's intrinsic high coefficient of adsorption (Kd) likely resulted in this COC adsorbing more to the soil. Based on soil sampling results in July 2008, naphthalene SPLP concentration averaged 75 µg/L for 2 soil samples collected in the source area (i.e., 71 µg/L for VWAE-SB-2930-08C and 80 µg/L for VWAE-SB-3436-08C). The maximum naphthalene concentration measured in July 2008 at MW-05 was 35 µg/L. However, considering the heterogeneity of subsurface conditions and groundwater has already been affected by target COCs, the groundwater COCs identified in the baseline HHRA, comprising 1,2-DCA, 2-methylnaphthalene, MTBE, naphthalene, and xylenes, as well as benzene (due to groundwater MCL exceedance), are included in the post-nitrate injection unsaturated soil sampling. Under a conservative assumption, a dilution factor of 2.1 (i.e., 75 µg/L ÷ 35 µg/L = 2.1) would be considered conservative and applicable for determination of the following soil PALs for evaluation of soil-to-groundwater leaching pathway.

TABLE 2
Soil SPLP PALS For AOC E

COCs	Soil PALs (SPLP)	Site	Source of PALs	*
Benzene	10.5 µg/L	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	
1,2-Dichloroethane	10.5 µg/L	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	
2-Methylnaphthalene	315 µg/L	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	
MTBE	252 µg/L	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	
Naphthalene	2.94 µg/L*	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	
Xylenes, total	21,000 µg/L	AOC E	Groundwater PRG adjusted by dilution factor of 2.1	

Note: This value is based on the conservative pilot study PRG of 1.4 µg/L. In that EPA's health-advisory life-time value of 100 µg/L for naphthalene would most likely be the final clean-up level in groundwater for naphthalene, an acceptable SPLP value would be 210 µg/L.

Other soil and/or groundwater analyses pertinent to pilot studies at AOC I and/or AOC E consist of VOCs, SVOCs, and TPH (ranges GRO, DRO and ORO) in soil; and TPH (ranges GRO, DRO, and ORO), sulfate, nitrate, TOC, soluble iron, soluble manganese, phospholipids fatty acid (PLFA), and quantitative polymerase chain reaction (qPCR) for naphthalene dioxygenase (NAH) and benzylsuccinate synthase (BSSA) in groundwater, all collectively referred to as indicator parameters. Selected VOCs and SVOCs in soil (i.e., the groundwater COCs) at AOC E will be evaluated for percent reduction based on July 2008 baseline sampling results. The other indicator parameters, including geochemical and microbial parameters, will be analyzed for performance evaluation of the pilot study technology. Although decision-making regarding the path forward following the pilot studies will not be based on the indicator parameters, PALs for these indicator parameters have been established and are included in Worksheet #15, including the rationale for defining the PALs. In general, the PALs are established based on the anticipated concentration range for the purpose of helping define the Project Quantitation Limit Goal, select appropriate analytical methods, and acquire proper laboratory subcontractors.

SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements (continued)

Sometimes the laboratory cannot achieve a quantitation limit low enough to satisfy the PALs. For example, although the QL is greater than the PAL for SPLP naphthalene in subsurface soil, the MDL is less than the PAL. Therefore, SPLP naphthalene, if present in a subsurface soil sample at or greater than the PAL, would likely be detected and reported by the laboratory instrumentation. The data point would be accompanied by a J-flag to indicate that the result is less than the QL. The same is true for naphthalene and bis(2-ethylhexyl)phthalate in groundwater, the only other instances of QL being greater than the PAL.

3. **What types of data are needed (matrix, target analytes, analytical groups, field screening, on-site analytical or off-site laboratory techniques, sampling techniques)?**

   Worksheets #10a, #10b, #15, #18a-1,#18a-2, and #18b define the matrices, analytical groups, and, where applicable, specific target analytes for AOC E and AOC I. Because of the nature of the pilot studies, the analyses are tailored to the COCs in groundwater, geochemical and microbial parameters in groundwater, and groundwater COCs in AOC E soil (with respect to leaching).

4. **How "good" do the data need to be in order to support the environmental decision?**

   Several types of data will be collected during the pilot studies. How good the data need to be is discussed by data type below.

   - **Visual Observations and PID Readings –** Visual observations and PID readings will be used at AOC E during soil boring sampling activities. Calibrating and operating the PID in accordance with the OVM SOP in Attachment 1 of the MQAPP (CH2M HILL, 2007b) are sufficient to provide data of appropriate quality.

   - **Laboratory Analytical Data**. Appropriate analytical protocol, data validation, QA/QC samples, and performing a data quality evaluation (DQE) to assess the availability and usability of the data will be used as the tools to ensure "good" data are acquired. Each of these is further discussed below:

     - **Appropriate Analytical Protocol –** See Worksheets #15, 19, 23, 24, 25, 28, and 30 and Question 5 below.

     - **Data Validation –** Validation of data increases the level of confidence in a data set for a particular data use. Data will be validated by an independent, third party data validator using guidance from the validation criteria outlined by the USEPA. Use of an independent, third party validator may serve to increase the public's confidence in the data because the validator provides an assessment of the data quality outside of any influence by the stakeholder parties. The validation criteria and guidance documents are listed in Worksheet #36. These documents will help the validator create a thorough and systematic approach to the validation process. The data validator will also recalculate 10 percent of the results from the raw laboratory data, which may identify laboratory errors in identification or quantification, if present.

SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements (continued)

- **QA/QC Samples –** QA/QC samples will be collected with the various media samples as a check on sampling and analytical protocol. Like data validation, the appropriate type and quantity of QA/QC samples is not an absolute. Field duplicates will be collected at a frequency of 1 per 10 field samples per matrix. Field duplicates help assess sample collection techniques and laboratory precision. Matrix spike/matrix spike duplicates (MS/MSDs) are collected at a frequency of 1 pair per 20 field samples per matrix. The frequency is such that there is one MS/MSD pair per laboratory analytical batch. MS/MSD samples are often required by the analytical method and/or data validation guidance. Equipment blanks are collected at a frequency of 1 per day per medium sampled when non-disposable equipment is utilized. Equipment blanks help assess equipment decontamination techniques and identify when contamination may have been carried over from one sample location to another. Equipment blanks will be collected in the field such that they are also subject to ambient field contamination. Trip blanks are collected at a frequency of 1 per cooler containing volatiles. Trip blanks accompany the empty sample containers while they are stored at the laboratory and shipped to the site, and while they are full and shipped back to the laboratory. Trip blanks are useful for assessing whether or not there is any contamination during periods of time when the samples are not directly supervised.
- **Data Quality Evaluation –** In order to support the environmental decisions, each result must be *available* to and *usable* for the project team. All data sets will undergo a DQE prior to using the data to make site-specific determinations. The terms *data availability* and *data usability* and the DQE process in general are described in Worksheet #37.

5. How much data should be collected (number of samples for each analytical group, matrix, and concentration)?

Worksheets #18a-1(for 2 ISCO injections) and#18b contain the number of samples per matrix per analytical group for AOC E and AOC I, respectively. Worksheet #18a-2 contains the number of samples per matrix per analytical group for AOC E in case that a contingency third ISCO injection is needed. Worksheets #15 contain the particular analytes, PALs, and quantitation limits (QLs). Worksheet #17 provides the rationale for the particular sampling at each site.

6. Where, when, and how should the data be collected/generated?

The soil and/or groundwater samples will be collected based on the scheduled sampling events in Worksheets #16a-1 (for 2 ISCO injections) or #16a-2 (for contingency 3 ISCO injections) for AOC E, and Worksheet #16b for AOC I. See Question #3 above and Worksheet #14 for how the data will be collected or generated.

SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements (continued)

7. Who will collect and generate the data? How will the data be reported?

CH2M HILL and its subcontractors will collect the data. Mitkem Laboratories and its subcontractor Microbial Insights, Inc. will generate the laboratory analytical data. The data will be evaluated and reported in the Progress Technical Memorandum and Pilot Study Report.

8. How will the data be archived?

The electronic data will be loaded into the Navy Installation Restoration Information System (NIRIS) database. Raw data, as well as data summary tables, will be included in the Progress Technical Memorandum and Pilot Study Report. Hardcopy data will be archived by CH2M HILL and the Navy in accordance with contract requirements.

9. List the Project Quality Objectives (PQOs) in the form of if/then qualitative and quantitative statements.

The general objectives of the decision analysis process are:

1. To determine if the in-situ remediation technologies can reduce the groundwater COCs to concentrations at or below the Pilot Study PRGs at AOC E and AOC I (i.e., groundwater PALs defined in Table 1 of Worksheet 11);
2. To determine if the in-situ remediation technology can reduce the groundwater COCs in soil (primarily naphthalene) at AOC E to levels that do not pose a soil-to-leaching concern (i.e., soil PALs defined in Table 2 of Worksheet 11);
3. To determine if the in-situ remediation technologies can reduce the cleanup timeframe.

The PQO statements for pilot studies are below:

AOC E

If COC concentrations in groundwater are equal to or less than the pilot study PRGs (Table 1) AND COC SPLP concentrations in the unsaturated zone soil are less than the soil SPLP PALs (Table 2, including consideration of the 230 µg/L value for naphthalene based on EPA's life-time exposure value of 100 µg/L), then the pilot study meets the goals to mitigate the unacceptable human health risk (including MCL exceedances) for potable groundwater use and prevent soil to groundwater leaching. In this case, no further action will be warranted, and AOC E will proceed to a no-further-action (NFA) proposed plan and record of decision (ROD).

It is recognized here that to ensure rebound does not occur, another round(s) (beyond those included in the pilot study) of groundwater sampling may be required for the COCs prior to approval of NFA. The need for additional groundwater sampling will be made upon completion of the pilot study.

SAP Worksheet 11 — Project Quality Objectives/Systematic Planning Process Statements (continued)

If COC concentrations in groundwater are above the PRGs (including consideration of 100 µg/L for naphthalene) OR COC SPLP concentrations in soil are above soil SPLP PRGs, the path forward (e.g., FS, additional pilot study, etc.) will be recommended in the pilot study report. The cleanup timeframe will be estimated based on the COC concentration trends and observed degradation rate constants, and will be compared with the baseline (i.e., untreated) natural attenuation timeframe to assist in making path forward recommendations. Because of the many combinations of concentrations detected and trends that may be observed, it is not possible at the preparation of the SAP to determine which scenario(s) would result in recommendations for a FS, additional pilot study, or other action.

AOC I

If COC concentrations in groundwater are equal to or less than the pilot study PRGs (Table 1), then the pilot study meets the goals to mitigate the unacceptable human health risk (including MCL exceedances) for potable groundwater use. In this case, NFA will be warranted, and AOC I will proceed to a NFA proposed plan and record of decision.

It is recognized here that to ensure rebound does not occur, another round(s) (beyond those included in the pilot study) of groundwater sampling may be required for the COCs prior to approval of NFA. The need for additional groundwater sampling will be made upon completion of the pilot study.

If COC concentrations in groundwater are above the PRGs (including consideration of 100 µg/L for naphthalene), the path forward (e.g., FS, additional pilot study, etc.) will be recommended in the pilot study report. The cleanup timeframe will be estimated based on the COC concentration trends and observed degradation rate constants, and will be compared with the baseline (i.e., untreated) natural attenuation timeframe to assist in making path forward recommendations. Because of the many combinations of concentrations detected and trends that may be observed, it is not possible at the preparation of the SAP to determine which scenario(s) would result in recommendations for a FS, additional pilot study, or other action.

SAP Worksheet 12-1 — Measurement Performance Criteria Table

Matrix: Subsurface Soil

Analytical Group: VOC

Concentration Level: Low (SW-846 8260C)

Measurement Performance Criteria Table – Field QC Samples

QC Sample	Analytical Group1	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Matrix Spike	VOC	1 per 20 field samples	Accuracy/Bias	See Worksheet 15	A
Matrix Spike Duplicate	VOC	1 per 20 field samples	Accuracy/Bias, Precision	See Worksheet 15	A
Field Duplicate	VOC	1 per 10 field samples	Precision	RPD < 30%	S&A
Equipment Rinseate Blank[2]	VOC	N/A: Disposable Equipment	N/A	N/A	N/A
Trip Blank	VOC	1 per cooler containing VOCs	Bias/Contamination	< 1/2 QL	S&A
Temperature Blank	VOC	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 Equipment blanks will not be collected for soil VOCs because all disposable equipment will be used.

SAP Worksheet 12-2 — Measurement Performance Criteria Table

Matrix: Subsurface Soil

Analytical Group: SVOC

Concentration Level: Low (SW-846 8270D-SIM)

Measurement Performance Criteria Table – Field QC Samples

QC Sample	Analytical Group1	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Matrix Spike	SVOC	1 per 20 field samples	Accuracy/Bias	See Worksheet 15	A
Matrix Spike Duplicate	SVOC	1 per 20 field samples	Accuracy/Bias, Precision	See Worksheet 15	A
Field Duplicate	SVOC	1 per 10 field samples	Precision	RPD < 30%	S&A
Equipment Rinseate Blank	SVOC	1 per day of sampling	Bias/Contamination	< 1/2 QL	S&A
Temperature Blank	SVOC	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

SAP Worksheet 12-3 — Measurement Performance Criteria Table

Matrix: Subsurface Soil					
Analytical Group: SPLPV					
Concentration Level: Low (W-846 1312, 8260C)					
Measurement Performance Criteria Table – Field QC Samples					
QC Sample	**Analytical Group**[1]	**Frequency**	**Data Quality Indicators (DQIs)**	**Measurement Performance Criteria**	**QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)**
Temperature Blank[2]	SPLPV	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet 12-4 — Measurement Performance Criteria Table

Matrix: Subsurface Soil					
Analytical Group: SPLPS					
Concentration Level: Low (SW-846 1312, 8270D)					
Measurement Performance Criteria Table – Field QC Samples					
QC Sample	**Analytical Group[1]**	**Frequency**	**Data Quality Indicators (DQIs)**	**Measurement Performance Criteria**	**QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)**
Temperature Blank[2]	SPLPS	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet 12-5 — Measurement Performance Criteria Table

Matrix: Subsurface Soil					
Analytical Group: WCHEM					
Concentration Level: Low (EPA 300.0, SW-846 9045C, Lloyd Kahn)					
Measurement Performance Criteria Table – Field QC Samples					
QC Sample	**Analytical Group[1]**	**Frequency**	**Data Quality Indicators (DQIs)**	**Measurement Performance Criteria**	**QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)**
Temperature Blank[2]	WCHEM	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet 12-6 — Measurement Performance Criteria Table

Matrix: Subsurface Groundwater

Analytical Group: VOC

Concentration Level: Low (SW-846 8260C)

Measurement Performance Criteria Table – Field QC Samples

QC Sample	Analytical Group[1]	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Matrix Spike	VOC	1 per 20 field samples	Accuracy/Bias	See Worksheet 15	A
Matrix Spike Duplicate	VOC	1 per 20 field samples	Accuracy/Bias, Precision	See Worksheet 15	A
Field Duplicate	VOC	1 per 10 field samples	Precision	RPD < 20%	S&A
Equipment Rinseate Blank	VOC	1 per day of sampling	Bias/Contamination	< 1/2 QL	S&A
Trip Blank	VOC	1 per cooler containing VOCs	Bias/Contamination	< 1/2 QL	S&A
Temperature Blank	VOC	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

SAP Worksheet 12-7 — Measurement Performance Criteria Table

Matrix: Subsurface Groundwater

Analytical Group: SVOC

Concentration Level: Low (SW-846 8270D)

Measurement Performance Criteria Table – Field QC Samples

QC Sample	Analytical Group[1]	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Matrix Spike	SVOC	1 per 20 field samples	Accuracy/Bias	See Worksheet 15	A
Matrix Spike Duplicate	SVOC	1 per 20 field samples	Accuracy/Bias, Precision	See Worksheet 15	A
Field Duplicate	SVOC	1 per 10 field samples	Precision	RPD < 20%	S&A
Equipment Rinseate Blank	SVOC	1 per day of sampling	Bias/Contamination	< 1/2 QL	S&A
Temperature Blank	SVOC	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

SAP Worksheet 12-8 — Measurement Performance Criteria Table

Matrix: Subsurface Groundwater					
Analytical Group: FMETAL					
Concentration Level: Low (SW-846 6010C)					
Measurement Performance Criteria Table – Field QC Samples					
QC Sample	**Analytical Group[1]**	**Frequency**	**Data Quality Indicators (DQIs)**	**Measurement Performance Criteria**	**QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)**
Temperature Blank[2]	FMETAL	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet 12-9 — Measurement Performance Criteria Table

Matrix: Subsurface Groundwater

Analytical Group: MICRO

Concentration Level: Low (PLFA, qPCR)

Measurement Performance Criteria Table – Field QC Samples

QC Sample	Analytical Group[1]	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Temperature Blank[2]	MICRO	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet 12-10 — Measurement Performance Criteria Table

Matrix: Subsurface Groundwater					
Analytical Group: WCHEM					
Concentration Level: Low (EPA 300.0, SM5310B)					
Measurement Performance Criteria Table – Field QC Samples					
QC Sample	**Analytical Group[1]**	**Frequency**	**Data Quality Indicators (DQIs)**	**Measurement Performance Criteria**	**QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)**
Temperature Blank[2]	WCHEM	1 per cooler	Accuracy / Representativeness	4±2°C	S

1 If information varies within an analytical group, separate by individual analyte.

2 The particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs.

SAP Worksheet #13 — Secondary Data Criteria and Limitations Table

The table below provides general information on how secondary data will be used in meeting the current project objectives and the limitations on their use in developing the SAP. Secondary data criteria and limitations tables are presented for each site where historical analytical data exist (applicable to the scope of work covered by this SAP), specifically to address the use and limitations of the historical analytical data.

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Data Types, Data Generation/ Collection Dates)	How Data Will Be Used	Limitations on Data Use
AOC E				
8 subsurface soil samples and 3 groundwater samples (newly installed wells MW-01 through MW-03) during Site Characterization in August and September 1998	Site Characterization Report for Site No. 2016, Prepared for United States Navy, Roosevelt Roads Naval Station, Ceiba, Puerto Rico, prepared by CH2M HILL in April 1999.	Soil and groundwater samples were analyzed for BTEX and TPH-DRO, TPH-GRO, and TPH-ORO	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development; data may be used to estimate natural attenuation rate before in-situ remediation pilot study
Sampling of 3 newly-installed wells (MW-04 through MW-06), and 2 existing wells (MW-02 and MW-03), and measuring free product thickness (approximately 0.1 ft) in MW-01 during Expanded PA/SI in April and May 2000	Expanded Preliminary Assessment/Site Investigation, U.S. Naval Ammunition Storage Detachment, Vieques Island, Puerto Rico, prepared by CH2M HILL in October 2000.	All groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, total and dissolved metals; Free product thickness was measured, if present	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development; data may be used to estimate natural attenuation rate before in-situ remediation pilot study and used as historical NAPL presence or thickness information
20 soil samples from 7 soil borings, sampling of 2 newly installed wells (MW-07 and MW-08), sampling of 4 existing monitoring wells (MW-02 though MW-03, MW-04, MW-06), measuring free product thickness in MW-01 (approximately 0.42 ft) and MW-05 (approximately 0.28 ft), and performing slug test in 2 wells during initial RI from May through August 2002 and September 2003	Draft Remedial Investigation/Feasibility Study Report, Area of Concern (AOC) E, Former Naval Ammunition Support Detachment, Vieques Island, Puerto Rico, prepared by CH2M HILL in February 2004.	Soil samples were analyzed for BTEX, Oil & Grease, TPH (C10-C28), and TPH (C6-C10);Groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, total and dissolved metals; Free product thickness was measured if present	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Soil and groundwater data were used for baseline HHRA in RI Report; Soil and groundwater data not directly associated with SAP development; data may be used to estimate natural attenuation rate before in-situ remediation pilot study and used as historical NAPL presence or thickness information; hydraulic conductivity data used to help develop the injection protocol
MPE pilot test data in monitoring wells MW-01 and MW-05 from June 2002 to August 2002	Final Remedial Investigation Report, Appendix H, Area of Concern (AOC) E, Former Naval Ammunition Support Detachment, Vieques, Puerto Rico, prepared by CH2M HILL in July, 2008	NAPL thickness before and after MPE pilot test; System influent and effluent water samples analyzed for TPH, O&G, BTEX; Effluent soil vapor air samples analyzed for TPH and BTEX	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development; NAPL removal by MPE documented

SAP Worksheet #13 — Secondary Data Criteria and Limitations Table (continued)

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Data Types, Data Generation/ Collection Dates)	How Data Will Be Used	Limitations on Data Use
Two rounds of groundwater samples from all wells without the presence of free product, and collection of surface soil samples from 7 locations, subsurface soil samples from 4 locations during the supplemental RI sampling from August 2004 to December 2005	Final Remedial Investigation Report, Area of Concern (AOC) E, Former Naval Ammunition Support Detachment, Vieques, Puerto Rico, prepared by CH2M HILL in July, 2008	Surface and subsurface soil samples were analyzed for VOCs, SVOCs, pesticides, PCBs, total metals, TOC, TPH-DRO, TPH-GRO, and TPH-ORO; Groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, total and dissolved metals, TDS, TPH-DRO, TPH-GRO,TPH-ORO, TPH (C10-C28), and TPH (C6-C10) ; Free product thickness was measured if present	Data may be used to estimate natural attenuation rate before in-situ remediation pilot study	Soil and groundwater were used for baseline HHRA in RI Report
2 surface soil and 13 subsurface soil samples from 2 soil borings (SB-20 and SB-21), and sampling 8 wells in July 2008 during an additional round of soil and groundwater sampling prior to FS and/or Pilot Study	Technical Memorandum – Proposed Pilot Study of In-Situ Remediation at Vieques AOC E, prepared by CH2M HILL in December, 2008.	Surface and subsurface soil samples were analyzed for VOCs, SVOCs, total metals, TOC, TPH-DRO, TPH-GRO, and TPH-ORO; subsurface soil samples also analyzed for pH, TOC, porosity, grain size, TOC, and SPLP for VOCs, SVOCs and metals; Groundwater samples were analyzed for VOCs, SVOCs, total and dissolved metals, inorganics, TPH-DRO, TPH-GRO,TPH-ORO, functional gene testing (PLFA etc.)	Subsurface soil data will be used in the Pilot Study Report as pre-injection baseline data for evaluation of pilot study performance; groundwater data may be used to estimate natural attenuation rate and microbial abundance before in-situ remediation pilot study; Both soil and groundwater data were used to establish PALs for the pilot study; Soil naphthalene SPLP and groundwater data were used to estimate the dilution factor for determination of soil SPLP PRGs.	Groundwater data may not represent pre-injection conditions of the pilot study (due to time between last sampling event and initiation of pilot study); therefore, a pre-injection baseline groundwater sampling event will be included in the pilot study; MTBE soil concentration (0.3 µg /kg) in July 2008 was less than the pilot study laboratory quantitation limit; however, the 2008 concentration was already less than EPA's leaching criterion (i.e., RSL). Soil data have no QC issues or limitations to their use as baseline soil concentrations.
AOC I				
3 surface soil samples collected during the Environmental Baseline Survey (EBS) in March 2000	Environmental Baseline Survey, Naval Ammunition Support Detachment Vieques, Vieques Island, Puerto Rico, prepared by Program Management Company in October 2000.	All surface soil samples (0-0.5 ft bgs) were analyzed for BTEX, TPH-GRO, TPH-DRO	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development

SAP Worksheet #13 — Secondary Data Criteria and Limitations Table (continued)

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Data Types, Data Generation/ Collection Dates)	How Data Will Be Used	Limitations on Data Use
26 surface and 26 co-located subsurface soil samples collected during PA/SI in November and December 2000	Expanded Preliminary Assessment/Site Investigation Phase II Seven Sites, Former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico, prepared by CH2M HILL in November 2002.	Surface and subsurface soil samples were analyzed for TCL VOCs, SVOCs, pesticides, PCBs, TAL metals, Petroleum Hydrocarbons by FL PRO (range C8-C40)	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development; Soil data used in the HHRA in RI report
Surface soil sampling at 18 locations, subsurface soil sampling at 7 locations, and installation and sampling of 7 monitoring wells during initial RI from August through September 2004	Interim Remedial Investigation Report for Area of Concern (AOC) I at the Former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico, prepared by CH2M HILL in January 2005.	Surface soil samples were analyzed for TCL SVOCs, TPH (C6-C10, C10-C28), hexavalent chromium, total chromium, TOC, and pH; Subsurface soil samples were analyzed for hexavalent chromium, total chromium, TOC, and pH; Groundwater samples were analyzed for TCL VOCs, SVOCs, pesticides, PCBs, TDS, total and dissolved TAL metals, and cyanide	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	Not directly associated with SAP development; Soil data used in the HHRA in RI report; September 2004 groundwater used in the HHRA in RI report
Installation of 2 monitoring wells and sampling of total 9 monitoring wells during supplemental RI from November 2005 to January 2006	Final Remedial Investigation Report, Area of Concern (AOC) I, Former Naval Ammunition Support Detachment, Vieques, Puerto Rico, prepared by CH2M HILL in June 2008	Groundwater samples were analyzed for TCL VOCs, SVOCs, total and dissolved TAL metals, cyanide, sulfate, nitrate, TDS, and TOC	Site history summaries. Understanding of historical activities that led to a CERCLA-related release.	January 2006 groundwater used in the HHRA in RI report
Sampling 9 wells in July 2008 during an additional round of soil and groundwater sampling prior to FS and/or Pilot Study	Technical Memorandum – Proposed Pilot Study of In-Situ Remediation at Vieques AOC I, prepared by CH2M HILL in November, 2008.	Groundwater samples were analyzed for VOCs, SVOCs, total and dissolved metals, inorganics, TPH-DRO, TPH-GRO,TPH-ORO, functional gene testing (PLFA etc)	Groundwater data may be used to estimate natural attenuation rate and microbial abundance before in-situ remediation pilot study; Groundwater data were used to develop PALs for selected parameters	Groundwater data may not represent pre-injection conditions of the pilot study (due to time between last sampling event and initiation of pilot study); therefore, a pre-injection baseline groundwater sampling event will be included in the pilot study

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SAP Worksheet #14a — Summary of Project Tasks for AOC E

Utility Clearance

NAVFAC Atlantic will be contacted for clearance of potential subsurface utilities at AOC E prior to the DPT injection. If necessary, each location will be excavated by hand or other approved method (i.e., posthole digger, air knife, etc.) from the zero to five-foot interval before direct-push activities begin.

Mobilization

Mobilizations will include CH2M HILL staff and subcontractors traveling to the island of Vieques to perform injection and sampling activities in accordance with the schedule in Worksheet # 16a-1 or #16a-2 (with a contingency injection).

Nitrate Injection in Unsaturated Zone Soil

Nitrate DPT Injection: A nitrate solution will be delivered to the targeted depth interval of 16 to 26 ft bgs in the unsaturated soil zone using direct push technology (DPT). Seven temporary injection points (IP-1 through IP-7) will be installed using a Geoprobe® or comparable unit. The DPT injection points will be spaced between 5 and 8 feet on center, as shown in Figure 6. The Geoprobe® will hydraulically push a probe, fitted with an injection screen, of an assumed length of 5 feet, to a depth of 5 feet into the target zone of 16-26 feet (i.e. to 21 feet). The probe tool will then be drawn back to expose the 5 foot injection screen to the formation from 16 to 21 feet bgs. Half the nitrate solution will be injected as a "slug" (if possible) followed by 20 gallons of water chaser to flush the nitrate from the borehole into the formation. The probe will then be pushed 5 feet further to 26 feet bgs, and the tool pulled back to expose the screen to the formation from 21 to 26 feet bgs. The injection process will be repeated in this interval. If the probe tool available has a screen length shorter than 5 feet, the zones exposed to the screen and slugs of nitrate injected, will be adjusted so that the nitrate is still injected throughout the full 16 to 26 foot length. If low flow conditions (i.e., less than 0.5 gpm) are encountered due to tight subsurface formation, the water chaser quantity will be adjusted down to 5 to 10 gallons. If the required quantity of nitrate solution (see Injection Protocol below) can be delivered to the subsurface through the single DPT injection event, then the borehole will be grouted after withdrawing the injection screen. At each location, an initial attempt will be made using the above method. If the injection rate is so slow that this method is not efficient, the borehole will be converted to a temporary injection point well as described below under Nitrate Gravity Trickle Feeding Via Temporary Injection Points (Contingency).

Nitrate Gravity Trickle Feeding Via Temporary Injection Points (Contingency): If the required quantity of nitrate solution cannot be injected in a single "slug" due to low permeability subsurface conditions, the boreholes will be converted into temporary injection points for subsequent gravity trickle feeding at AOC E. The temporary injection points will be constructed of 1-inch-diameter schedule 40 polyvinyl chloride (PVC), with 10 feet of 0.020 inch slotted screen interval (16 to 26 ft bgs). The borehole annulus will be backfilled with clean sand to approximately one foot above the top of the screen. A 2-foot bentonite seal and approximately 13 feet of bentonite-concrete grout will fill the remainder of the annulus. Gravity trickle infiltration will deliver the remaining nitrate solution to the unsaturated zone soil using manifold piping connecting to an on-site storage tank.

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

Nitrate Demand: Stoichiometrically, approximately 4.9 pounds of nitrate are required to degrade 1 pound of hydrocarbons. The theoretical total quantity of nitrate (including a safety factor of 5) to remediate the hydrocarbon mass (VOCs and SVOCs) based on data collected in July 2008 in a treatment area of approximately 15 feet by 10 feet was calculated to be roughly 200 pounds. This converts to a dosing requirement of 296 pounds of calcium nitrate fertilizer (Viking Ship® Brand CALCINIT™, additional product information in Attachment G).

Injection Protocol:

- The 296 pounds of calcium nitrate fertilizer will be mixed with approximately 675 gallons of water, in order to prepare a 5 percent solution that is approximately 710 gallons. The solution will be prepared in 200-gallon polytank in batches.
- Approximately 710 gallons of 5 percent calcium nitrate fertilizer solution will be injected at seven points over a 10-foot vertical interval at each point (from 16 to 26 ft bgs) or about 10 gallons of 5 percent solution per vertical foot.
- The calcium nitrate solution will be applied to the points under low pressures (5 to 20 psi).
- The 5 percent calcium nitrate fertilizer solution will be injected using a Geoprobe™ unit and ancillary equipment (mixing tanks, pumps, etc.).
- A total of 20 gallons of water chaser (potentially less depending on formation conditions) will be injected at each injection point to flush the nitrate from the borehole into the formation.
- The solution is anticipated to be approximately 20 percent of the pore volume surrounding each injection point, based on the total volume of nitrate solution and water chaser injected to the targeted unsaturated zone for soil treatment (15 ft long x 10 ft wide x 10 ft deep) with a porosity of 0.34.
- Assuming a flow rate of 2 gpm, approximately 8 hours of injection will be required to deliver the total gallons of fluids (710 gallons of 5% calcium nitrate fertilizer solution plus up to 140 gallons of water chaser distributed into 7 points).
- Assuming that seven injection points to 26 feet bgs can be installed by DPT in 1-2 days, it is estimated that the injection point installations and solution delivery can be completed in approximately 3 - 4 days.

The proposed unsaturated zone soil treatment using denitrification based bioremediation (DBB) should reduce the naphthalene concentrations in the unsaturated zone soil through enhanced anaerobic degradation, thereby reducing or eliminating the soil-to-groundwater leaching potential. This technology should not destroy the binding (adsorption) between the soil organic materials and COCs; therefore, it should not increase the potential for residual NAPL mobilization. A buffering infiltration and treatment zone (26 to 32 ft bgs) below the nitrate injection depth zone (16 to 26 ft bgs) will allow further reductions of COC concentrations by denitrification. Should residual COC reach the water table, these COCs will be treated by the proposed persulfate ISCO and subsequent ORC treatments.

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

Persulfate Injection in Groundwater (ISCO)

The proposed ISCO application involves injecting sodium hydroxide activated Klozur® (sodium persulfate) solution into four 2-inch-diameter existing monitoring wells: MW-01, MW-03, MW-4, and MW-05 by gravity feeding or injected with low pressure (up to 30 psi) if gravity feeding cannot reach an injection rate of 0.5 gpm. The wells' screen interval is from 40 to 50 ft bgs. Figure 6 shows the locations of ISCO treatment wells.) Klozur® sodium persulfate technical literature is located in Attachment G.

SAP Worksheet #14a— Summary of Project Tasks for AOC E (continued)

Immediately before the injection, one round of groundwater sampling will be performed for parameters defined in Worksheet #18a-1 or #18a-2. The results will serve as the baseline conditions for evaluating ISCO and EISB performance.

The first ISCO injection will occur during the same mobilization as the nitrate injection (month 1), the second ISCO injection will occur during month 4 (see Worksheet 16a-1), and, if needed, the third ISCO injection will occur during month 7 (see Worksheet 16a-2 contingency schedule) if COC concentrations are still above the threshold concentrations described in Worksheet #10a. The following paragraphs describe the injection demand and the protocol that will be followed during each ISCO injection event.

Oxidant Demand: A total of 3,344 pounds of Klozur® persulfate and 3,200 pounds (300 gallons) of sodium hydroxide will be required for an approximately 50 ft by 25 ft treatment area. This dosage will be cut in half for the second and potential third series of injections. The lateral and vertical extent of the treatment area is based on the COC concentrations in monitoring wells MW-01 and MW-05. Analytical results from these wells exceeded their respective PRGs during the additional groundwater sampling performed in July 2008 and historical groundwater sampling data reported in the RI report dated July 2008.

Injection Protocol:

- Typical ISCO injections target pore volume displacements between 20 and 50 percent. Since the existing monitoring wells are being used as injection points, water displacement around each well will be kept to a minimum (promoting mixing rather than displacement). This will be achieved by distributing the oxidant solution using gravity feeding or low pressure of up to 30 psi, and using a total solution volume to achieve between 10 and 20 percent of the pore volume for an estimated radius of influence (ROI) of 7 to 9 ft.
- Prior to the injection, during background sampling, field water quality parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), persulfate, and depth to water will be monitored in MW-01, MW-03, MW-4, and MW-05 serving as ISCO application wells.
- 3,344 pounds of Klozur® persulfate will be mixed with approximately 1,672 gallons of water and prepared in a polytank (tank volume between 200 and 1,000 gallons) in batches to prepare a 10 percent Klozur® persulfate solution of approximately 1,760 gallons.

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

- Sodium hydroxide will be added to the persulfate solution immediately prior to injection. For each 200-gallon-batch 10 percent Klozur® persulfate solution, approximately 363 pounds (34 gallons) of sodium hydroxide will be added.
- The injection amount and sequence is listed below:
  - Inject approximately 440 gallons of 10 percent Klozur® persulfate with 800 pounds (75 gallons) of sodium hydroxide per well
  - Inject approximately 20 gallons of water chaser per well
  - In order to minimize water displacement around the wells during ISCO applications, subsurface distribution of the persulfate and sodium hydroxide solution will first be attempted into monitoring wells MW-3, MW-4, and MW-5 by a gravity feed system. The average hydraulic conductivity is 7.06×10^{-5} centimeters per second [cm/sec], which represents a relatively tight formation. If flow rate is less than 0.5 gpm, then the injection method will be switched to a low pressure injection system (up to 30 psi).
  - Subsequent to the injections in MWs3, 4, and 5, MW-1 will be pumped during which time enhanced desorption between the initial three injection wells and MW-01 and any mobilized residual product around MW-01 will immediately be recovered. Parameters such as ORP, conductivity and DO will be monitored continuously (above-ground) and pH, temperature, and conductivity periodically down-well with a downhole probe. In addition persulfate test kits will be used periodically. Once the extracted groundwater shows persulfate impact from the 3 surrounding wells, extraction will cease. The remaining ¼ of activated persulfate solution will then be injected into MW-01.
- The low pressure injection will be completed using ancillary equipment (mixing tanks, pumps, etc.) under a low to moderate wellhead pressure of 5 to 30 psi. The injection pump will be rated at 5 to 500 psi with a flowrate capacity of up to 10 gpm.
- If 440 gallons per injection well is too high for the formation to accept during gravity feeding or low pressure injection, the amount of water mixed with persulfate and sodium hydroxide will be decreased by increments of 10 to 20 percent, resulting in an increase in persulfate and sodium hydroxide concentration being applied.
- Assuming a flow rate of 2 to 4 gpm, approximately two to three working days of injection will be required to deliver the total gallons of fluids (approximately 1,760 gallons).

Persulfate exhibits relatively low soil oxidant demand compared with other types of oxidants (e.g., permanganate). Considering the relatively small scale of the planned ISCO application, the oxidant demand was assumed to be an average of 2 g persulfate for 1 kg of soil based on the potential for some residual NAPL. The planned oxidant dosing took into account the stoichiometric demand of the actual COC concentrations in the groundwater. Monitoring following the ISCO applications will help assess if the dosing is adequate. The oxidant demand decreases for areas having been treated before; thus, the demand of 1 g persulfate per kg of soil should be sufficient for re-applications of ISCO to maintain oxidative conditions in the aquifer. However, as stated above, monitoring will be conducted and the dosing adjusted as necessary based on the observations.

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

NAPL was historically present in monitoring wells MW-01 and MW-05 based on the RI Report for AOC E dated July 2008. During the implementation of a multi-phase extraction (MPE) pilot test from June 2002 to August 2002, the recoverable NAPL was removed, and only residual NAPL was measured. In March 2006, less than 0.1 foot of NAPL was measured in MW-01 and no measurable NAPL thickness was found in MW-05. The additional round of groundwater sampling conducted in July 2008 did not identify any NAPL in either MW-01 or MW-05. 0.59 feet of product was however measured and bailed from MW-1 on January 27, 2010.

If any recoverable NAPL is present during baseline groundwater sampling, a hand bailer will be used to remove it. Any minor residual NAPL, if present, should be addressed by the multiple ISCO injection events and/or the ORC sock treatment.

Installation of ORC Socks (EISB)

In-situ bioremediation will be enhanced by installing ORC socks into the four 2-inch-diameter wells that were treated with ISCO: MW-01, MW-03, MW-04, and MW-05. The screen intervals of monitoring wells are 40 to 50 ft bgs. In each well, approximately ten ORC sock elements (each 1 foot long) will be laced together and installed in accordance with the vendor's installation instructions/SOP (see Attachment E). The ORC socks release molecular oxygen that supports aerobic biodegradation for up to 9 months. The socks will be deployed approximately 7 months after the last ISCO injection (i.e., month 15 for 2 ISCO injections or month 18 for contingency 3 ISCO injections). The oxygen-delivery socks will remain in the wells for 9 months and be removed at month 24 or month 27 (contingency). Additional technical information and an MSMSD for ORC are located in Attachment G.

The proposed EISB involving ORC socks will be a polishing step following the persulfate ISCO treatment for the groundwater, and will serve to enhance, not interfere with, the processes initiated by ISCO treatment. In fact, the ISCO treatment might improve the efficiency and longevity of the EISB due to the potential to have residual high ORP and dissolved oxygen from the ISCO that could result in lower oxygen demand by the groundwater. Therefore, the combination of the proposed treatment technologies is likely to have a synergistic effect, with very low risk of interference.

Soil and Groundwater Sampling (for Offsite Laboratory Analysis)

Post-injection unsaturated zone soil samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2). A total of five split spoon soil samples will be collected from two soil borings (SB-22 and SB-23; see Figure 5) in general accordance with *Master Standard Operating Procedures, Protocols, and Plans* (CH2M HILL, July 2009). Two soil samples from each boring will be collected from the highest COC concentration depth intervals observed in July 2008 event for laboratory analysis: one from the unsaturated zone where injection occurred (16-20 ft bgs), and one from the smear zone below the injection interval (28-32 ft bgs). In addition, one field duplicate sample will be collected from one soil sampling depth in one soil boring. This equates to five total soil samples collected from the two soil boring locations. The samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2). The samples will be analyzed for VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLPs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TOC, pH, TPH (ranges GRO, DRO, and ORO), and nitrate.

One round of pre-injection groundwater samples will be collected from four monitoring wells (MW-01, MW-03, MW-04, and MW-05) during Month 1 as baseline data. Two rounds of post-injection performance groundwater sampling will be conducted for the two ISCO injection scenario as listed in the schedule in Worksheet #16a-1. Three rounds of post-injection performance groundwater sampling will be conducted for the three ISCO injection scenario as listed in the schedule in Worksheet #16a-2. The sampling will be conducted in general accordance with groundwater sampling SOPs in Draft Final Master Standard Operating Procedures, Protocols, and Plans, SOP B-1. All the groundwater samples will be analyzed for the COCs identified in Worksheet #10a, comprising VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), as well as TPH (ranges GRO, DRO, and ORO) and other geochemical parameters. Groundwater samples will be collected from one well (MW-01) for analysis of microbial parameters. See numbers of samples and parameters in Worksheet #18a-1, #18a-2, and #15).

Field Parameter Monitoring and Groundwater Gauging (Onsite Measurement)

Pre-injection and post-injection field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), persulfate, and depth to groundwater will be monitored in MW-01, MW-03, MW-04, and MW-05 following the schedule in Worksheets #16a-1 or #16a-2 (contingency), in general accordance with the Draft Final Master SOPs, Protocols, and Plans SOP C-1 (Calibration and Measurement with Field Instruments) and Master SOPs H2 (Water Level Measurement). Visual and instrument (e.g., oil/water interface probe) monitoring for sheen (or thicker) NAPL will be included during the gauging and sampling activities due to its past presence and the relatively high-magnitude groundwater fluctuations observed over time. If a sheen is observed, the ISCO injections will likely oxidized it. If recoverable NAPL is observed, a hand bailer will be used to remove any recoverable NAPL, then the necessity of using another round of ISCO to remove residual NAPL will be evaluated at that time.

Monitoring Well Development

Existing wells will be redeveloped if turbidity readings do not stabilize to within approximately 10 percent of each other over three consecutive readings during low-flow sampling (assuming the well has sufficient capacity to sustain low-flow purging and sampling). To the extent practicable, the development protocol in the well installation SOP will be followed for existing wells being redeveloped and any deviation from the SOP will be documented in field notes and the associated report.

SAP Worksheet #14a — Summary of Project Tasks for AOC E (continued)

Equipment Decontamination

Equipment decontamination will follow SOPs in the Draft Final Master SOPs, SOPs E1 and E2.

Investigation-Derived Waste Management

IDW will be managed and disposed of in accordance with the Master Waste Management Plan (Master WMP) (Master SOPs). Liquid and solid IDW will be sampled for full TCLP and RCI to determine the disposal options unless historical IDW sample data for this site is deemed sufficient by the disposal subcontractor.

Surveying

The locations of injection points or existing monitoring wells (if necessary) will be surveyed by CH2M HILL's field team using a GPS unit in accordance with the SOP in Master SOPs Attachment H-7.

Shipments

All analytical samples will be sent by Fed Ex which has on-island staff. All equipment will be shipped to the Camp Garcia CH2M HILL office on Vieques. All samples will be shipped in accordance with the SOP in Master SOPs H-5 "Packaging and Shipping Procedures for Samples Not Considered Dangerous Goods."

Quality Control

All quality control samples are listed on Worksheet 20. In reference to the field tasks, all field work will be overseen by a field team leader who is responsible for the quality control of the sampling and make sure the proper SOPs are followed for each task.

Sample Analysis

The laboratory will maintain, test, inspect, and calibrate analytical instruments (Worksheets #24 and #25). The laboratory will analyze soil and groundwater samples for various groups of parameters as shown on Worksheets # 15 and #18.

Data Management

The Project EIS, Juan Acaron, is responsible for data tracking and storage. In addition a third party data validator will receive all analytical data from the laboratory and the data will be validated prior to its use by the Navy. All validated analytical data will be loaded into the NIRIS database.

Procedures for Recording and Correcting Data

Field data will be recorded in field logbooks.

Project Assessment/Audit: Worksheets #31 and #32

Data Validation: Worksheets #35 and #36

Data Usability Assessment: Worksheet #37.

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SAP Worksheet #14b — Summary of Project Tasks for AOC I

Mobilization

Mobilizations will include CH2M HILL staff and subcontractors traveling to the island of Vieques to perform injection and sampling activities in accordance with the schedule in Worksheet # 16b.

Persulfate Injection in Groundwater (ISCO)

The proposed ISCO application involves injecting sodium hydroxide alkaline activated Klozur® (sodium persulfate) solution into four existing 2-inch-diameter monitoring wells: MW-02, MW-03, MW-4, and MW-07 by gravity feeding or injected with low pressure (up to 30 psi) if gravity feeding cannot reach an injection rate of 0.5 gpm. The wells' screen intervals are between 24 and 43 ft bgs. Figure 11 shows the locations of ISCO treatment wells.

Immediately before the injection, one round of groundwater sampling will be performed for parameters defined in Worksheet #18a-2. The results will serve as the baseline conditions for evaluating ISCO and EISB performance. The ISCO injection at AOC I will occur during the same mobilization as for ISCO injection at AOC E (month 1) (See Worksheet #16b). The following describes the ISCO application, oxidant demand, and injection protocol.

Oxidant Demand: A total of 835 pounds of Klozur® persulfate and 800 pounds (75 gallons) of sodium hydroxide will be required for an approximately 25 ft by 25 ft treatment area.

Injection Protocol:

- Typical ISCO injections target pore volume displacements between 20 and 50 percent. Since the existing monitoring wells are being used as injection points), water displacement around each well will be kept to a minimum (promoting mixing rather than displacement). This will be achieved by distributing the oxidant solution using gravity feeding or low pressure of up to 30 psi, and using a total solution volume to achieve between 10 and 20 percent of the pore volume for an estimated radius of influence (ROI) of 5 ft.
- Prior to the injection, field water quality parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), persulfate, and depth to water will be monitored in four wells serving as ISCO application wells (MW-02, MW-03, MW-4, and MW-07), and one downgradient well (MW-05).
- 835 pounds of Klozur® persulfate will be mixed with approximately 1,900 gallons of water and prepared in a polytank (tank volume between 200 and 1,000 gallons) in batches to prepare a 5 percent Klozur® persulfate solution of approximately 1,945 gallons.

SAP Worksheet #14b — Summary of Project Tasks for AOC I (continued)

- sodium hydroxide will be added to the persulfate solution immediately prior to injection. For each 200-gallon-batch 5 percent Klozur® persulfate solution, approximately 85 pounds (8 gallons) of sodium hydroxide will be added.
- The injection amount and sequence is listed below:
  - Inject approximately 485 gallons of 5 percent Klozur® persulfate with 200 pounds (18.8 gallons) of sodium hydroxide per well
  - Inject approximately 20 gallons of water chaser per well
- In order to minimize water displacement around the wells during ISCO applications, subsurface distribution of the persulfate and sodium hydroxide solution will first be attempted into the four designated monitoring wells by a gravity feed system. The average hydraulic conductivity is 1.4×10^{-3} centimeters per second [cm/sec], which represents a moderately permeable aquifer. If flow rate is less than 0.5 gpm, then the injection method will be switched to a low pressure injection system (up to 30 psi).
- If 485 gallons per injection well is too high for the formation to accept via gravity feeding or low pressure injection, the amount of water mixed with persulfate and sodium hydroxide will be decreased by increments of 10 to 20 percent, resulting in an increase in persulfate and sodium hydroxide concentration being applied.
- The low pressure injection will be completed using ancillary equipment (mixing tanks, pumps, etc.) under a low to moderate wellhead pressure of 5 to 30 psi. The injection pump will be rated at 5 to 500 psi with a flowrate capacity of up to 10 gpm. Assuming a flow rate of 2 to 4 gpm, approximately two to three working days of injection will be required to deliver the total gallons of fluids (approximately 1,945 gallons).

Installation of ORC Socks (EISB)

In-situ bioremediation will be enhanced by installing ORC socks into the four 2-inch-diameter ISCO treatment wells (MW-02, MW-03, MW-04, and MW-07) and one downgradient well (MW-05). The ORC socks will be installed at the depths of individual 10-foot-well screen intervals. The ORC sock installation depths of monitoring wells are below:

Well ID	ORC Sock Installation Depth Intervals
MW-02	31- 41 ft bgs
MW-03	24 - 34 ft bgs
MW-04	30 - 40 ft bgs
MW-05	32- 42 ft bgs
MW-07	33- 43 ft bgs

SAP Worksheet #14b — Summary of Project Tasks for AOC I (continued)

In each well, approximately ten ORC socks elements (each 1 foot long) will be laced together and installed in accordance with the vendor's SOP (see Attachment E). The ORC socks release molecular oxygen that supports aerobic biodegradation for up to 9 months. The socks will be deployed approximately 3 months after the ISCO injection (i.e., month 4). The oxygen-delivery socks will remain active in the wells for 9 months and then be removed during month 13.

Groundwater Sampling (for Offsite Laboratory Analysis)

One round of pre-injection baseline groundwater sampling will be performed during month 1. One round of post-injection groundwater samples will be collected from five monitoring wells (MW-02, MW-03, MW-04, MW-05, and MW-07) during Month 4. Another round of groundwater sampling (post-EISB polishing) will be conducted during Month 15 (Worksheet #16b). Groundwater samples will be collected in general accordance with groundwater sampling SOPs in the Master SOPs, SOP B-1. All the groundwater samples will be analyzed for site-specific COCs identified in the Worksheet #10b, comprising VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOCs (bis [2-ethylhexyl] phthalate, 2-methylnaphthalene, and naphthalene). Other geochemical parameters will also be analyzed (see numbers of samples and parameters in Worksheet #18b and #15).

Field Parameter Monitoring and Groundwater Gauging (Onsite Measurement)

Pre-injection and post-injection field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), persulfate, and depth to groundwater will be monitored in MW-02, MW-03, MW-04, MW-05, and MW-07 following the schedule in Worksheets #16b, in general accordance with Master SOPs C-1 (Calibration and Measurement with Field Instruments) and Master SOPs H-2 (Water Level Measurement).

Monitoring Well Development

Existing wells will be redeveloped if turbidity readings do not stabilize to within approximately 10 percent of each other over three consecutive readings during low-flow sampling (assuming the well has sufficient capacity to sustain low-flow purging and sampling). To the extent practicable, the development protocol in the well installation SOP will be followed for existing wells being redeveloped and any deviation from the SOP will be documented in field notes and the associated report.

Equipment Decontamination

Equipment decontamination will follow SOPs in Master SOPs E-1, E-2.

SAP Worksheet #14b — Summary of Project Tasks for AOC I (continued)

Investigation-Derived Waste Management

IDW will be managed and disposed of in accordance with the Master Waste Management Plan (WMP) (Master SOPs, Protocols, and Plans). Liquid and solid IDW will be sampled for full TCLP and RCI to determine the disposal options unless historical IDW sample data for this site is deemed sufficient by the disposal subcontractor.

Shipments

All analytical samples will be sent by Fed Ex which has on-island staff. All equipment will be shipped to the Camp Garcia CH2M HILL office on Vieques. All samples will be shipped in accordance with the SOP in Master SOPs H-5 "Packaging and Shipping Procedures for Samples Not Considered Dangerous Goods."

Quality Control

All quality control samples are listed on Worksheet 20. In reference to the field tasks, all field work will be overseen by a field team leader who is responsible for the quality control of the sampling and make sure the proper SOPs are followed for each task.

Sample Analysis

The laboratory will maintain, test, inspect, and calibrate analytical instruments (Worksheets #24 and #25). The laboratory will analyze soil and groundwater samples for various groups of parameters as shown on Worksheets #15 and #18.

Data Management

The Project EIS, Juan Acaron, is responsible for data tracking and storage. In addition a third party data validator will receive all analytical data from the laboratory and the data will be validated prior to its use by the Navy. All validated analytical data will be loaded into the NIRIS database.

Procedures for Recording and Correcting Data

Field data will be recorded in field logbooks.

Project Assessment/Audit: Worksheets #31 and #32

Data Validation: Worksheets #35 and #36

Data Usability Assessment: Worksheet #37.

SAP Worksheet #15-1 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil

Analytical Group: VOC

Analyte	CAS Number	10% of maximum detection from July, 2008 (µg/kg)	Laboratory QL from July, 2008 (µg/kg)	Project Action Limit[1] (µg/kg)	Project Quantitation Limit Goal[2] (µg/kg)	Laboratory-Specific				
						QLs (µg/kg)	MDLs (µg/kg)	LCL (%)	UCL (%)	RPD (%)
Methyl-tert-butyl ether (MTBE)	1634-04-4	0.13	5	5	5	5	0.75	75	126	40
Benzene	71-43-2	39	5	39	19.5	5	0.33	75	125	40
1,2-Dichloroethane	107-06-2	N/A	5	5	5	5	0.36	70	135	40
Xylene, total	1330-20-7	7200	5	7200	3600	5	0.44	83	125	40

N/A: Not applicable

1 The Project Action Limit is the greater of "10% of maximum detection from July 2008" or "Laboratory QL from July, 2008." Such PALs are only for purposes of choosing Project Quantitation Limit Goals. For compounds with significant detects, the objective is to observe a decreasing trend to about an order of magnitude lower than observed in July 2008. For compounds with low detects or nondetects, it is desirable to approximate the previous laboratory QL for data comparability. All analytical data reported on a dry weight basis.

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

SAP Worksheet #15-2 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil

Analytical Group: SVOC

Analyte	CAS Number	10% of maximum detection from July, 2008 (µg/kg)	Laboratory QL from July, 2008 (µg/kg)	Project Action Limit[1] (µg/kg)	Project Quantitation Limit Goal[2] (µg/kg)	Laboratory-Specific				
						QLs (µg/kg)	MDLs (µg/kg)	LCL (%)	UCL (%)	RPD (%)
Naphthalene	91-20-3	760	3.8	760	380	3.3	1.2	45	135	40
2-Methylnaphthalene	91-57-6	1400	3.8	1400	700	3.3	1.1	45	135	40

1 The Project Action Limit is the greater of "10% of maximum detection from July 2008" or "Laboratory QL from July, 2008." Such PALs are only for purposes of choosing Project Quantitation Limit Goals. For compounds with significant detects, the objective is to observe a decreasing trend to about an order of magnitude lower than observed in July 2008. For compounds with low detects or nondetects, it is desirable to approximate the previous laboratory QL for data comparability.

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

SAP Worksheet #15-3 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil									
Analytical Group: SPLPV									
Analyte	**CAS Number**	**AOC E Pilot Study PRG[3] (µg/L)**	**Project Action Limit[1] (µg/L)**	**Project Quantitation Limit Goal[2] (µg/L)**	**Laboratory-Specific**				
					QLs (µg/L)	**MDLs (µg/L)**	**LCL (%)**	**UCL (%)**	**RPD (%)**
Methyl-tert-butyl ether (MTBE)	1634-04-4	252	252	126	5	0.43	65	125	40
Benzene	71-43-2	10.5	10.5	5.25	5	0.39	80	120	40
1,2-Dichloroethane	107-06-2	10.5	10.5	5.25	5	0.33	70	130	40
Xylene, total	1330-20-7	21000	21000	10500	5	0.45	81	121	40

1 The Project Action Limit is "AOC E Pilot Study PRG.", both are adjusted by a dilution factor of 2.1

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The source is indicated in the AOC E Pilot Study Memorandum (CH2M HILL, December 2008).

SAP Worksheet #15-4 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil

Analytical Group: SPLPS

Analyte	CAS Number	AOC E Pilot Study PRG[3] (µg/L)	Project Action Limit[1] (µg/L)	Project Quantitation Limit Goal[2] (µg/L)	Laboratory-Specific				
					QLs[4] (µg/L)	MDLs (µg/L)	LCL (%)	UCL (%)	RPD (%)
Naphthalene	91-20-3	2.9	2.9	1.5	1	0.67	40	100	40
2-Methylnaphthalene	91-57-6	315	315	157	1	0.83	45	105	40

1 The Project Action Limit is "AOC E Pilot Study PRG.", both are adjusted by a dilution factor of 2.1

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The source is indicated in the AOC E Pilot Study Memorandum (CH2M HILL, December 2008).

4 Mitkem will modify the method to provide an additional 1ppb calibration standard for aqueous SVOCs.

SAP Worksheet #15-5 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil										
Analytical Group: WCHEM										
Analyte	**CAS Number[4]**	**Expected Nitrate Concentration Post-Injection**	**Range of Detections from July, 2008**	**Project Action Limit[2]**	**Project Quantitation Limit Goal[3]**	**Laboratory-Specific[1]**				
						QLs	**MDLs**	**LCL (%)**	**UCL (%)**	**RPD (%)**
Nitrogen, Nitrate (as N)	14797-55-8	500 mg/kg	N/A	500 mg/kg	250 mg/kg	2.6 mg/kg	0.124 mg/kg	90	110	20
pH	PH	N/A	6.64-8.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total organic carbon (TOC)	TOC	N/A	903-11,700 mg/kg	903 mg/kg	450 mg/kg	100 mg/kg	10 mg/kg	80	120	50

N/A: Not applicable

1 QLs, MDLs, and limits for precision and accuracy are not applicable to pH data.

2 For nitrate, the PAL is "Expected Nitrate Concentration Post-Injection." For TOC, the PAL is the lowest detection from July 2008. The TOC PAL is only for purpose of choosing a Project Quantitation Limit Goal. It is desirable to approximate the previous laboratory QL for data comparability.

3 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

4 The CAS numbers for pH and TOC are contractor-specific.

SAP Worksheet #15-6 — Reference Limits and Evaluation Table

Matrix: Groundwater

Analytical Group: VOC

Analyte	CAS Number	List E	List I	AOC E Pilot Study PRG[3] (µg/L)	AOC I Pilot Study PRG[3] (µg/L)	Project Action Limit[1] (µg/L)	Project Quantitation Limit Goal[2] (µg/L)	Laboratory-Specific				
								QLs (µg/L)	MDLs (µg/L)	LCL (%)	UCL (%)	RPD (%)
Methyl-tert-butyl ether (MTBE)	1634-04-4	X		120	N/A	120	60	5	0.43	65	125	40
Benzene	71-43-2	X	X	5	5	5	5	5	0.39	80	120	40
1,2-Dichloroethane	107-06-2	X	X	5	5	5	5	5	0.33	70	130	40
1,2-Dichloropropane	78-87-5		X	N/A	5	5	5	5	0.72	75	125	40
Xylene, total	1330-20-7	X		10000	10000	10000	10000	5	0.45	81	121	40

N/A: Not applicable

1 The Project Action Limit is the lower of "AOC E Pilot Study PRG" or "AOC I Pilot Study PRG."

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The sources are indicated in the AOCs E and I Pilot Study Memoranda (CH2M HILL, November and December 2008).

SAP Worksheet #15-7 — Reference Limits and Evaluation Table

Matrix: Groundwater

Analytical Group: SVOC

Analyte	CAS Number	List E	List I	AOC E Pilot Study PRG[3] (µg/L)	AOC I Pilot Study PRG[3] (µg/L)	Project Action Limit[1] (µg/L)	Project Quantitation Limit Goal[2] (µg/L)	Laboratory-Specific				
								QLs[4] (µg/L)	MDLs (µg/L)	LCL (%)	UCL (%)	RPD (%)
Naphthalene	91-20-3	X	X	1.4	1.4	1.4	1.4	1	0.67	40	100	40
2-Methylnaphthalene	91-57-6	X	X	150	150	150	75	1	0.83	45	105	40
bis(2-Ethylhexyl)phthalate	117-81-7		X	N/A	6	6	6	5	2.5	40	125	40

N/A: Not applicable

1 The Project Action Limit is the lower of "AOC E Pilot Study PRG" or "AOC I Pilot Study PRG."

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The sources are indicated in the AOCs E and I Pilot Study Memoranda (CH2M HILL, November and December 2008)

4 Mitkem will modify the method to provide an additional 1ppb calibration standard for aqueous SVOCs.

SAP Worksheet #15-8 — Reference Limits and Evaluation Table

Matrix: Groundwater									
Analytical Group: FMETAL									
Analyte4	**CAS Number**	**Maximum Detection from July, 2008 (µg/L)**	**Project Action Limit[1] (µg/L)**	**Project Quantitation Limit Goal[2] (µg/L)**	**Laboratory-Specific**				
					QLs (µg/L)	**MDLs (µg/L)**	**LCL (%)**	**UCL (%)**	**RPD (%)**
Iron	7439-89-6	4240	4240	2120	200	61	80	120	20
Manganese	7439-96-5	4040	4040	2020	50	0.96	80	120	20

1 The Project Action Limit is the "Maximum Detection from July 2008." The purpose of dissolved iron and manganese analysis is to confirm the presence of an oxidation environment post-injection. The maximum dissolved iron and manganese concentrations from the previous investigation should decrease post-injection. Therefore, it is desirable to observe dissolved iron and manganese concentrations on the order of the maximum detected values from July 2008. The purpose of these PALs is solely for selecting Project Quantitation Limit Goals.

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

SAP Worksheet #15-9 — Reference Limits and Evaluation Table

Matrix: Groundwater

Analytical Group: MICRO

Analyte	CAS Number[3]	Project Action Limit[2]	Project Quantitation Limit Goal[2]	Laboratory-Specific[1]				
				QLs	MDLs	LCL (%)	UCL (%)	RPD (%)
Cells	CELLS	N/A	1500 cells/mL	1500 cells/mL	500 cells/mL	80	120	90
Firmicutes	FIRMICUTES	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
Proteobacteria	PROTEOBACT	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
Anaerobic metal reducers	ANAERMETRED	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
Actinomycetes	ACTINOMYC	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
General Nsats	GENNSAT	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
Eukaryotes	EUKARYOTES	N/A	N/A (%)	N/A (%)	N/A (%)	N/A	N/A	N/A
Slowed Growth	SLOWGRO	N/A	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)
Decreased Permeability	DECPERM	N/A	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)	N/A (ratio)
Napthalene Dioxygenase	NAH	N/A	1 gc/mL	1 gc/mL	1 gc/mL	80	120	90
Benzyl Succinante Synthase	bssA	N/A	1 gc/mL	1 gc/mL	1 gc/mL	80	120	90

gc/mL: "Gene copies per milliliter"

N/A: Not applicable

1 QLs, MDLs, and limits for precision and accuracy are not applicable to all MICRO analyses.

2 There are no screening levels or project action limits for MICRO analyses.

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The CAS numbers for MICRO analytes are contractor-specific.

SAP Worksheet #15-10 — Reference Limits and Evaluation Table

Matrix: Groundwater

Analytical Group: WCHEM

Analyte	CAS Number[3]	MCL-Groundwater	Range of Detections from July, 2008	Project Action Limit[1]	Project Quantitation Limit Goal[2]	Laboratory-Specific				
						QLs	MDLs	LCL (%)	UCL (%)	RPD (%)
Sulfate	14808-79-8	NC	12.5-13.3 mg/L	12.5 mg/L	6.25 mg/L	5 mg/L	0.021 mg/L	90	110	20
Nitrogen, Nitrate (as N)	14797-55-8	10 mg/L	N/A	10 mg/L	5 mg/L	0.130 mg/L	0.006 mg/L	90	110	20
Total organic carbon (TOC)	TOC	NC	2.3-18.9 mg/L	2.3 mg/L	1.15 mg/L	1 mg/L	0.288 mg/L	80	120	20

NC: No screening level for this compound.

N/A: Not applicable

1 For nitrate, the PAL is "MCL-Groundwater." For TOC, the PAL is the lowest detection from July 2008. The TOC PAL is only for purpose of choosing a Project Quantitation Limit Goal. It is desirable to observe concentrations in the same range as per the previous investigation.

2 The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

3 The CAS number for TOC is contractor-specific.

SAP Worksheet #15-11 — Reference Limits and Evaluation Table

Matrix: Subsurface Soil

Analytical Group: TPH

Analyte	CAS Number	PREQB UST Corrective Action Level (µg/kg)	Project Action Limit[1] (µg/kg)	Project Quantitation Limit Goal[2] (µg/kg)	Laboratory-specific				
					QLs (µg/kg)	MDLs (µg/kg)	LCL (%)	UCL (%)	RPD (%)
TPH-Gasoline Range Organics	TPH-GRO	100000	100000	50000	2500	1000	80	120	20
TPH-Diesel Range Organics	TPH-DRO	100000	100000	50000	9000	1400	60	140	20
TPH-Oil Range Organics	TPH-ORO	100000	100000	50000	12000	2500	N/A	N/A	N/A

[1] The Project Action Limit is "PREQB UST Corrective Action Level"

[2] The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

N/A - Not Applicable. Quality control spike for TPH-DRO and TPH-ORO analyses use diesel fuel as the spike analyte, which is measured in the DRO portion of the test.

SAP Worksheet #15-12 — Reference Limits and Evaluation Table

Matrix: Groundwater

Analytical Group: TPH

Analyte	CAS Number	PREQB UST Corrective Action Level (µg/L)	Project Action Limit[1] (µg/L)	Project Quantitation Limit Goal[2] (µg/L)	Laboratory-specific				
					QLs (µg/L)	MDLs (µg/L)	LCL (%)	UCL (%)	RPD (%)
TPH-Gasoline Range Organics	TPH-GRO	50000	50000	25000	100	3.4	80	120	20
TPH-Diesel Range Organics	TPH-DRO	50000	50000	25000	280	42	60	140	20
TPH-Oil Range Organics	TPH-ORO	50000	50000	25000	350	88	N/A	N/A	N/A

[1] The Project Action Limit is "PREQB UST Corrective Action Level"

[2] The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.

N/A - Not Applicable. Quality control spike for TPH-DRO and TPH-ORO analyses use diesel fuel as the spike analyte, which is measured in the DRO portion of the test.

SAP Worksheet #16a-1 — AOC E Project Schedule / Timeline Table (2 ISCO Injection Events)

Tasks	January 2010 - July 2012																												
	Months																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Unsaturated Zone Soil Treatment with Nitrate																													
Direct Push Installation of Screened Injection Points	X																												
Nitrate Injection	X																												
Post-injection Unsaturated Zone Soil Boring Sampling/Analysis[3]															X											X			
ISCO of Saturated Zone and Groundwater																													
ISCO Injection into Existing Wells	X			X																									
Field Parameter Monitoring and Well Gauging [1]	X										X				X											X			
Groundwater Sample Collection and Analysis [2]	X										X															X			
ISCO Progress Tech Memo and Recommendations														X															
Sustained Aerobic Environment Polishing																													
Installation of Oxygen Socks into Existing Wells															X														
Removal of Oxygen Socks for Well Equilibration																								X					
Draft Pilot Study Report																													X

Notes:

[1] Field parameters, persulfate, and depth to groundwater will be collected during month 1, 11, and 26 groundwater sampling events and prior to installing the ORC socks.

[2] Groundwater samples will be collected during month 1 (baseline), 7 months after the second ISCO injection event, and approximately 2 months after removing the. ORC socks. Groundwater samples will not be collected during the month 4 injection event to allow sufficient time for oxidant to dissipate.

[3] Soil samples will be collected at month 15. If the SPLP analytical results are below PALs, then no additional soil sampling will be necessary. If SPLP analytical results are still above PALs, a second round of soil samples will be collected at the conclusion of the pilot study from locations directly adjacent to the previous soil samples.

The pilot study schedule assumes a start date of January 2010, which is subject to change per agency's final approval on the pilot study SAP.

The schedule assumes two rounds of ISCO injection prior to ORC sock treatment. The schedule is subject to revision if additional round of ISCO injection is needed.

X indicates month of field deployment event or report delivery; actual dates may vary depending on mobilization conditions and validated data availability in the database.

Shading indicates anticipated duration of treatment and equlibration of aquifer.

Refer to worksheet 18 for list of field parameters to be monitored and list of analytes to be collected.

SAP Worksheet #16a-2 — AOC E Project Schedule / Timeline Table (Contingency Plan- 3 ISCO Injection Events)

Tasks	January 2010 - November 2012																																	
	Months																																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Unsaturated Zone Soil Treatment with Nitrate																																		
Direct Push Installation of Screened Injection Points	x																																	
Nitrate Injection	x																																	
Post-injection Unsaturated Zone Soil Boring Sampling/Analysis[3]																				x											x			
ISCO of Saturated Zone and Groundwater																																		
ISCO Injection into Existing Wells	x			x									x																					
Field Parameter Monitoring and Well Gauging [1]	x										x									x											x			
Groundwater Sample Collection and Analysis [2]	x										x									x											x			
ISCO Progress Tech Memo and Recommendations														x																				
Sustained Aerobic Environment Polishing																																		
Installation of Oxygen Socks into Existing Wells																				x														
Removal of Oxygen Socks for Well Equilibration																													x					
Draft Pilot Study Report																																		x

Notes:

[1] Field parameters, persulfate, and depth to groundwater will be collected during month 1, 11, 20, and 31 groundwater sampling events.

[2] Groundwater samples will be collected during month 1 (baseline), 7 months after the second ISCO injection event, 7 months after the third ISCO injection event, and approximately 2 months after removing the ORC socks. Groundwater samples will not be collected during the month 4 and month 20 injection events to allow sufficient time for oxidant to dissipate.

[3] Soil samples will be collected at month 20. If the SPLP analytical results are below PALs, then no additional soil sampling will be necessary. If, however, SPLP analytical results are still above PALs, a second round of soil samples will be collected at the conclusion of the pilot study from locations directly adjacent to the previous soil samples.

The pilot study schedule assumes a start date of January 2010, which is subject to change per agency's final approval on the pilot study SAP.

The schedule assumes three rounds of ISCO injections prior to ORC sock treatment. If a third round of ISCO injection is not necessary, Schedule 16-1a will be followed.

X indicates month of field deployment event or report delivery; actual dates may vary depending on mobilization conditions and validated data availability in the database.

Shading indicates anticipated duration of treatment and equilibration of aquifer.

Refer to worksheet 18 for list of field parameters to be monitored and list of analytes to be collected.

SAP Worksheet #16b — AOC I Project Schedule / Timeline Table

Tasks	January 2010 - October 2011																					
	Months																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
In-Situ Chemical Oxidant (ISCO) Injection	X																					
Field Parameter Monitoring and Well Gauging [1]	X							X											X			
Groundwater Sample Collection and Analysis [2]	X							X											X			
Installation of Oxygen-Releasing Socks (EISB)								X														
Removal of Oxygen Socks for Well Equilibration																	X					
ISCO Status Progress Report											X											
Draft Pilot Study Report																						X

Notes:

[1] Field parameters, sulfate, persulfate, and depth to groundwater will be collected during month 1, 8, and 18 groundwater sampling events.

[2] Groundwater samples will be collected during month 1 (baseline), 7 months after the ISCO injection event, and approximately 2 months after removing the ORC socks.

The pilot study schedule assumes a start date of January 2010, which is subject to change per agency's final approval of the pilot study SAP.

X indicates month of field deployment event or report delivery; actual dates may vary depending on mobilization conditions and validated data availability in the database.

Shading indicates anticipated duration of treatment and equilibration of aquifer.

Refer to worksheet 18 for list of field parameters to be monitored and list of analytes to be collected.

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SAP Worksheet 17 — Sampling Design and Rationale

Given that the scope of work under this SAP consists of pilot study, the sampling rationale and design are based on determining whether the pilot study objectives defined in worksheet #10 can be met.

The soil sampling data collected during July 2008 will be used as the baseline data for soil at AOC E, and new baseline data will be collected at both sites for groundwater prior to implementing remediation technologies. Post-injection unsaturated zone soil sampling data (VOCs and SVOCs) will be compared with the baseline to evaluate the percent reductions. Post-injection unsaturated zone soil SPLP data and multiple rounds of post-injection groundwater sampling results will be compared with the baseline data to evaluate whether the proposed PRGs can be met, or the soil to groundwater leaching (primarily naphthalene) concern can be reduced or eliminated.

AOC E

The baseline HHRA contained in the *Final Remedial Investigation Report* (CH2M HILL, 2008a) identified five groundwater COCs comprising 1,2-DCA, 2-methylnaphthalene, MTBE, naphthalene, and xylenes; however, groundwater samples collected and analyzed in July 2008 indicated that only benzene, naphthalene, and MTBE exceeded their respective Pilot Study PRGs (CH2M HILL, 2008b). Due to the potential for fluctuations in groundwater concentrations and elevations, all of the COCs identified in the HHRA plus benzene (exceedance of MCL observed in July 2008) and non-COC TPH (ranges GRO, DRO, and ORO) will be analyzed during the pilot study. Other groundwater geochemical parameters, including TOC, sulfate, nitrate, soluble iron, and soluble manganese will also be analyzed as performance indicator parameters to monitor ISCO and nitrate distribution and to help interpret the other data and evaluate the effectiveness of enhanced bioremediation. TOC will be monitored for evaluation of ISCO distribution and efficiency, as the oxidation process oxidizes organic matter and causes TOC to decrease. DO, nitrate, soluble iron, and soluble manganese, and sulfate concentrations will provide evidence of dominant electron acceptors in the groundwater, and help determine whether an aerobic environment is established and maintained for the EISB. Persulfate will be measured using field analytical tests to monitor oxidant demand distribution and ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate). Pre-injection and post-injection field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO) will be measured to determine if aerobic aquifer conditions are established and maintained. Water table elevations and the potential presence of free product will also be measured pre- and post-injection to help ensure the applicability of the technology and determine the actual depth of smear zone soil sampling (i.e., to ensure it is above the water table).

Microbial parameters, comprising PLFA, and qPCR for abundance of microbes such as naphthalene dioxygenase (NAH) and benzylsuccinate synthase (BSSA), will be analyzed in one well (MW-01) as indicators for enhanced aerobic biodegradation of naphthalene and benzene. The analysis of PLFA and qPCR would provide insight into the biomass, biological community structure, physiological status, and the presence of select enzymes and microbes.

PLFA is a main component of the membrane (essentially the "skin") of microbes and provides a powerful tool for assessing microbial responses to changes in their environment. This type of analysis provides direct information for assessing and monitoring sites where bioremediation

SAP Worksheet 17 — Sampling Design and Rationale (continued)

processes, including natural attenuation, are of interest. Analysis of the types and amount of PLFA provides a broad based understanding of the entire microbial community with information obtained in three key areas: viable biomass, community structure and metabolic activity. The parameters analyzed for PLFA have been included in Worksheet #15-9, specifically, including total biomass cell counts, firmicutes (Gram negative bacteria), proteobacteria, anaerobic metal reducers, actinomycetes, general Nsats, eukaryotes, slowed growth, and decreased permeability. Because groups of bacteria differ in their metabolic capabilities, determining which bacterial groups are present and their relative distributions within the community can provide information on what metabolic processes are occurring at that location. This in turn can also provide another line of evidence on the subsurface conditions (i.e., oxidation/reduction status, aerobic/anaerobic etc.). Ratios for slowed growth and for decreased permeability of the cell membrane provide information on the "health" of the Gram negative community, that is, how this population is responding to the conditions present in the environment.

qPCR is a technique for identifying microbes directly from their DNA and for quantifying specific enzymes in a microbial population. It has the advantage over traditional culturing methods in sensitivity, accuracy, objectivity, and reproducibility. The quantitative analysis can be done on uncultured bacteria, thereby eliminating the need for a pure culture, special growth requirements, growth conditions, and preliminary testing. The presences of key enzymes that activate the initial step in a degradation pathway are considered strong evidence of microbial capabilities for biodegradation potential at a specific site. For aromatic hydrocarbon degradation in an anaerobic environment, benzyl succinate synthase (BSSA) is generally considered indicative of a microbial community's biodegradation potential. Following the ISCO/EISB treatment, it is anticipated that BSSA would decrease. On the other hand, increase in quantities of the aerobic functional gene naphthalene dioxygenase (NAH) would suggest an aerobic environment has been established following EISB treatment. The proposed qPCR analysis includes measuring the abundance of NAH and BSSA in groundwater in one of the monitoring well of AOC E during the pilot study period. The reference limits are also provided in Worksheet #15-9. The lab SOPs for Microbial Insights are also included in Attachment D of the SAP. Thus qPCR monitoring of the population shifting of BSSA and NAH during the ISCO/EISB treatment can be used to help assess the efficiency of the pilot study.

Soil samples collected in July 2008 at AOC E indicated that the highest COC concentrations are present at the depth intervals near the smear zone. The SPLP analysis results indicate that the concentration of VOCs (chloromethane, ethylbenzene, toluene, and xylene) in the unsaturated soils result in leachate concentrations at least one order of magnitude below the MCL or drinking-water health-advisory standard; therefore, the unsaturated zone soil should not be a concern for VOCs as a continuous source for soil to groundwater leaching pathway. The SVOC naphthalene is the only groundwater COC whose data collected in 2008 suggested its concentration in soil may leach from unsaturated soil into groundwater and result in a groundwater concentration exceeding the conservative pilot study PRG of 1.4 µg/L. Considering the heterogeneity of subsurface conditions and groundwater has already been affected by target COCs, the groundwater COCs identified in the baseline HHRA, comprising 1,2-dichloroethane (1,2-DCA), 2-methylnaphthalene, MTBE, naphthalene, and xylenes, as well as benzene, are included in the post-nitrate injection unsaturated

SAP Worksheet 17 — Sampling Design and Rationale (continued)

soil sampling. Soil analyses will comprise the COCs and TPH in soil for comparison to baseline concentrations to evaluate percent reduction, and COCs in leachate (i.e. SPLP) to evaluate whether the post-injection COC concentrations in soil pose a potential leaching concern.

AOC I

The baseline HHRA contained in the *Final Remedial Investigation Report* (CH2M HILL, 2008a) identified six groundwater COCs comprising benzene, bis(2-ethylhexyl)phthalate, 1,2-DCA, 1,2-dichloroprpane, 2-methylnaphthalene, and naphthalene; however, groundwater samples collected in July 2008 indicated that only benzene and naphthalene exceeded the Pilot Study PRGs. Due to the potential for fluctuations in groundwater concentrations and elevations, the six COCs identified in the HHRA are selected for performance sampling during the pilot study at AOC I.

Other groundwater geochemical parameters, including TOC, sulfate, nitrate, soluble iron, and soluble manganese will also be analyzed as performance indicator parameters to monitor ISCO distribution and to help interpret the other data and evaluate the effectiveness of enhanced bioremediation. TOC will be monitored for evaluation of ISCO distribution and efficiency, as the oxidation process oxidizes organic matter and causes TOC to decrease. DO, nitrate, soluble iron, and soluble manganese, and sulfate concentrations will provide evidence of dominant electron acceptors in the groundwater, and help determine whether an aerobic environment is established and maintained for the EISB. Persulfate will be measured using field analytical tests to monitor oxidant demand distribution and ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate). Pre-injection and post-injection field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO) will be measured to determine if aerobic aquifer conditions are established and maintained. Water table elevations and the potential presence of free product will also be measured pre- and post-injection to help ensure the applicability of the technology and determine the actual depth of smear zone soil sampling (i.e., to ensure it is above the water table).

No soil sampling is proposed for AOC I because no COCs were identified in soil whose concentration would likely result in soil-to-groundwater leaching concerns.

The rationale for the matrices (soil and groundwater) to be sampled, the number of samples per matrix, the analytical groups, and the concentration levels are discussed in Worksheets #10, #11, #14, #15, and #18. Sample location figures are provided in Attachment A.

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SAP Worksheet #18a-1 — AOC E Sampling Locations and Methods/SOP Requirements Table (*2 ISCO Injections*)

Station ID	Sample ID	Matrix	Depth [1] (units)	Analytical Group	Number of Samples (identify field duplicates) [4, 5]	Sampling SOP Reference [2, 3]
VWAE-SB22	VWAE-SB22-TTBB-MMYY	Subsurface Soil (Unsaturated Zone and Smear Zone)	16-20, 28-32 (ft bgs)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLPs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH-DRO, GRO, and ORO, TOC, pH, and nitrate	3 (including 1 Duplicate, month 15) Possibility of 3 additional (including 1 Duplicate, month 26)[1]	See Worksheet 21
VWAE-SB23	VWAE-SB23-TTBB-MMYY	Subsurface Soil (Unsaturated Zone and Smear Zone)	16-20, 28-32 (ft bgs)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLPs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH-DRO, GRO, and ORO, TOC, pH, and nitrate	2 (month 15) Possibility of 2 additional (month 26) see Worksheet 14a	See Worksheet 21
VWAE-MW01	VWAE-MW01-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TOC, phospholipids fatty acid (PLFA), and quantitative polymerase chain reaction (qPCR) for naphthalene dioxygenase (NDO) and benzylsuccinate synthase (BSSA), TPH-DRO, GRO, and ORO,	3 (month 1, 11 and 26)	See Worksheet 21
VWAE-MW03	VWAE-MW03-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC,	6 (3 Duplicates; month 1, 11 and 26)	See Worksheet 21
VWAE-MW04	VWAE-MW04-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC	3 (month 1, 11 and 26)	See Worksheet 21
VWAE-MW05	VWAE-MW05-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC	3 (month 1, 11 and 26)	See Worksheet 21

1 Post-injection confirmatory soil samples will be collected from 2 borings at depth intervals with highest VOC and SVOCs concentrations observed in July 2008, to assess the effectiveness of the denitrification-based bioremediation by comparing to results of those of the baseline pre-injection soil sampling in July 2008. If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2).

2 SOP or worksheet that describes the sample collection procedures.

3 In addition to the samples above collected for laboratory analysis, field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), and persulfate will be measured per field monitoring schedule described in Worksheet 16a-1. The monitoring wells will be gauged for depth to water prior-injection and during each subsequent performance monitoring event. The wells will also be gauged for the presence and thickness of LNAPL.

4 Other than duplicates, QA/QC samples are not included in this worksheet. Please refer to Worksheet 28 for the required QA/QC samples.

5 The number of samples assumes no contingency third ISCO injection is required for AOC E.

TTBB = depth below ground surface of the top of the sample interval (TT) and the bottom of the sample interval (BB).

SAP Worksheet #18a-2 — AOC E Sampling Locations and Methods/SOP Requirements Table (*Contingency – 3 ISCO Injections*)

Station ID	Sample ID	Matrix	Depth [1] (units)	Analytical Group	Number of Samples (identify field duplicates) [4]	Sampling SOP Reference [2], [3]
VWAE-SB22	VWAE-SB22-TTBB-MMYY	Subsurface Soil (Unsaturated Zone and Smear Zone)	16-20, 28-32 (ft bgs)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLPs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH-DRO, GRO, and ORO, TOC, pH, and nitrate	3 (including 1 Duplicate, month 20) Possibility of 3 additional (including 1 Duplicate, month 31)[1]	See Worksheet 21
VWAE-SB23	VWAE-SB23-TTBB-MMYY	Subsurface Soil (Unsaturated Zone and Smear Zone)	16-20, 28-32 (ft bgs)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLPs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH-DRO, GRO, and ORO, TOC, pH, and nitrate	2 (month 20) Possibility of 2 additional (month 31)[1]	See Worksheet 21
VWAE-MW01	VWAE-MW01-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TOC, phospholipids fatty acid (PLFA), and quantitative polymerase chain reaction (qPCR) for naphthalene dioxygenase (NDO) and benzylsuccinate synthase (BSSA), TPH-DRO, GRO, and ORO,	4 (month 1, 11, 20, and 31)	See Worksheet 21
VWAE-MW03	VWAE-MW03-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC	8 (4 Duplicates; month 1, 11, 20 and 31)	See Worksheet 21
VWAE-MW04	VWAE-MW04-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC	8 (month 1, 11, 20, and 31)	See Worksheet 21
VWAE-MW05	VWAE-MW05-MMYY	Groundwater	40 – 50 ft bgs (screen interval)	VOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), sulfate, nitrate, soluble iron, soluble manganese, TPH-DRO, GRO, and ORO, and TOC	4 (month 1, 11, 20,and 31)	See Worksheet 21

1 Post-injection confirmatory soil samples will be collected from 2 borings at depth intervals with highest VOCs and SVOCs concentrations measured in July 2008, to assess the effectiveness of the denitrification -based bioremediation by comparing to results of those of the baseline pre-injection soil sampling in July 2008. If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2).

2 SOP or worksheet that describes the sample collection procedures.

3 In addition to the samples above collected for laboratory analysis, field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), t and persulfate will be measured per field monitoring schedule described in Worksheet 16a-2. The monitoring wells will be gauged for depth to water prior--injection and during each subsequent performance monitoring events. The wells will also be gauged for the presence and thickness of LNAPL.

4 Other than duplicates, QA/QC samples are not included in this worksheet. Please refer to Worksheet 28 for the required QA/QC samples.

TTBB = depth below ground surface of the top of the sample interval (TT) and the bottom of the sample interval (BB).

SAP Worksheet #18b — AOC I Sampling Locations and Methods/SOP Requirements Table

Station ID	Sample ID	Matrix	Screen Depth (ft bgs)	Analytical Group	Number of Samples (identify field duplicates) [3]	Sampling SOP Reference [1, 2]
VWAI-MW02	VWAI-MW02-MMYY	Groundwater	31 - 41	VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOC (bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene), nitrate, sulfate, soluble iron, soluble manganese, and TOC	3 (month 1, 4 and 15)	See Worksheet 21
VWAI-MW03	VWAI-MW03-MMYY	Groundwater	24 - 34	VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOC (bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene), nitrate, sulfate, soluble iron, soluble manganese, and TOC	3 (month1, 4 and 15)	See Worksheet 21
VWAI-MW04	VWAI-MW04-MMYY	Groundwater	30 - 40	VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOC (bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene), nitrate, sulfate, soluble iron, soluble manganese, and TOC	6 (including 3 duplicates; month 1, 4 and 15)	See Worksheet 21
VWAI-MW05	VWAI-MW05-MMYY	Groundwater	32 - 42	VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOC (bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene), nitrate, sulfate, soluble iron, soluble manganese, and TOC	3 (month1, 4 and 15)	See Worksheet 21
VWAI-MW07	VWAI-MW07-MMYY	Groundwater	33 - 43	VOCs (benzene, 1,2-dichloroethane, and 1,2-dichloropropane), SVOC (bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, and naphthalene), nitrate, sulfate, soluble iron, soluble manganese, and TOC	3 (month1, 4 and 15)	See Worksheet 21

1 SOP or worksheet that describes the sample collection procedures.

2 In addition to the above samples collected for laboratory analysis, field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO), and persulfate will be measured per field monitoring schedule described in Worksheet 16b. The monitoring wells will be gauged for depth to water prior and post-injection and during each subsequent performance monitoring event.

3 Other than duplicates, QA/QC samples are not included in this worksheet. Please refer to Worksheet 28 for the required QA/QC samples.

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SAP Worksheet #19 — Analytical SOP Requirements Table

Matrix	Analytical Group	Analytical and Preparation Method / SOP Reference[1]	Containers (number, size, and type)	Sample Volume[2] (units)	Preservation Requirements (chemical, temperature, light-protected)	Maximum Holding Time[3] (preparation / analysis)
SB	VOC	SW-846 8260C / 90.0012	2 of 40mL VOC vials, preweighed, with stir bar	5g per vial[4]	5mL DI water, (4±2) °C	48 hours to freeze at laboratory (or in field) / 14 days to analyze[5]
			1 of 40mL VOC vial, preweighed, with stir bar	5g per vial[4]	5mL methanol, (4±2) °C	14 days to analyze
SB	SVOC	SW-846 3550, 3570, 3540, 8270D-SIM / 50.0052, 50.0100, 50.0053, 70.0033	1 of 8oz CWM soil jar	30g	(4±2) °C	14 days / 40 days
SB	TPH	SW-846 8015M / 90.0038	1 of 40mL VOC vial, preweighed, with stir bar	5g per vial[4]	5mL methanol, (4±2) °C	14 days to analyze
		SW-846 8015M / 60.0050	1 of 8oz CWM soil jar	30g	(4±2) °C	14 days / 40 days
SB	SPLPV	SW-846 1312, 8620C / 110.0031, 90.0012	1 of 8oz CWM soil jar	100g	(4±2) °C	Post-leach, 14 days
SB	SPLPS	SW-846 1312, 3510, 8270D / 110.0031, 50.0051, 70.0011		100g	(4±2) °C	Post-leach, 7 days / 40 days
SB	WCHEM	EPA 300.0 / 110.0032, 100.0400	1 of 8oz CWM soil jar	30g	(4±2) °C	Post-leach, 48 hours
		SW-846 9045C / 100.0112		10g		As soon as possible
		Lloyd Kahn / 100.0410		5g		14 days
GW	VOC	SW-846 8260C / 90.0012	2 of 40mL VOA vial	40mL per vial	HCl to pH < 2, (4±2) °C	14 days
GW	SVOC	SW-846 3510, 8270D / 50.0051, 70.0011	2 of 1L amber	1000mL	(4±2) °C	7 days / 40 days
GW	TPH	SW-846 8015M / 90.0038	2 of 40mL VOA vial	40mL per vial	HCl to pH < 2, (4±2) °C	14 days
		SW-846 8015M / 60.0050	2 of 1L amber	1000mL	(4±2) °C	7 days / 40 days
GW	FMETAL[6]	SW-846 3005, 6010C / 100.0003, 100.0111	1 of 250mL HDPE	50mL	HNO_3 to pH < 2, (4±2) °C	6 months
GW	MICRO	MI SOP-qPCR	1 of 1L HPDE or 1 of Bio-flo filter	1000mL[7]	(4±2) °C	24-48 hours
GW	MICRO	MI SOP-PLFA	2 of 1L HDPE or 1 of Bio-flo filter	2000mL[7]	(4±2) °C	24-48 hours

SAP Worksheet #19 — Analytical SOP Requirements Table (continued)

Matrix	Analytical Group	Analytical and Preparation Method / SOP Reference[1]	Containers (number, size, and type)	Sample Volume[2] (units)	Preservation Requirements (chemical, temperature, light-protected)	Maximum Holding Time[3] (preparation / analysis)
GW	WCHEM	EPA 300.0 / 100.0400	1 of 250mL HDPE	50mL	(4±2) °C	28 days for sulfate, 48 hours for nitrate
		SM5310B / SM5310B	3 of 40mL VOA vial	40mL per vial	H_3PO_4 to pH < 2, (4±2) °C	28 days

1 Specify the appropriate reference letter or number from the Analytical SOP References table (Worksheet #23).

2 Provide the minimum sample volume or mass requirement if it differs from the container volume.

3 Maximum holding time is calculated from the time the sample is collected to the time the sample is prepared/extracted.

4 The field team will utilize a scale to spot-check (~1/10 samples) that the soil-grabber syringe device provides 5±1g.

5 If the field team cannot ship on the same day as sample collection, the low-level pre-preserved vials will be placed into a freezer as soon as possible. Date/time in and date/time out of freezer will be recorded. In this instance, the holding time, 48-hours, will be evaluated against the time spent not frozen. It will be assumed that the samples are frozen when in the freezer and not frozen before being placed into the freezer or while in transit.

6 The field team will field-filter FMETALs so that preserved bottleware can be used.

7 To provide HDPE containers, collect the entire sample volume. To provide Bio-flo filters, record the volume which has passed through the filter, discard the water, and submit the filter for analysis.

SAP Worksheet #20 — Field Quality Control Sample Summary Table

Matrix	Analytical Group	No. of Sampling Locations[2]	No. of Field Duplicates	No. of MS/MSDs[1]	No. of Field Blanks[4]	No. of Equip. Blanks[3,4]	No. of VOA Trip Blanks[3]	Total No. of Samples to Lab
AOC E Unsaturated Zone Soil Sampling (Two Events – Months 15 and 26; sample quantities reflect one event) -or- AOC E Contingency[5] (Two Events – Months 20 and 31; sample quantities reflect one event)								
SB	VOCs	4	1	1			1	8
SB	SVOCs	4	1	1		1		8
SB	TPH (GRO)	4	1	1			1	8
SB	TPH (DRO and ORO)	4	1	1		1		8
SB	SPLPV	4						4
SB	SPLPS	4						4
SB	WCHEM (NO_3, pH, TOC)	1						1
AOC E Groundwater Sampling (Three Events – Months 1, 11, and 26; sample quantities reflect one event) -or- AOC E Contingency[5] (Four Events – Months 1, 11, 29, and 31; sample quantities reflect one event)								
GW	VOCs	4	1	1		2	2	11
GW	SVOCs	4	1	1		2		9
GW	TPH (GRO)	4	1	1		2	2	11
GW	TPH (DRO and ORO)	4	1	1		2		9
GW	FMETALs	4						4
GW	WCHEM (NO_3, SO_4, TOC)	4						4
GW	MICRO (PLFA, NAH, bssA)	1						1

SAP Worksheet #20 — Field Quality Control Sample Summary Table (continued)

Matrix	Analytical Group	No. of Sampling Locations[2]	No. of Field Duplicates	No. of MS/MSDs[1]	No. of Field Blanks[4]	No. of Equip. Blanks[3,4]	No. of VOA Trip Blanks[3]	Total No. of Samples to Lab
AOC I Groundwater Sampling (Three Events – Months 1, 8, and 19; sample quantities reflect one event)								
GW	VOCs	5	1	1		2	2	12
GW	SVOCs	5	1	1		2		10
GW	TPH (GRO)	5	1	1		2	2	12
GW	TPH (DRO and ORO)	5	1	1		2		10
GW	FMETALs	5						5
GW	WCHEM (NO_3, SO_4, TOC)	5						5

1 Although the MS/MSD is not typically considered a field QC, it is included here because location determination is often established in the field.

2 If samples will be collected at different depths at the same location, count each discrete sampling depth as a separate sampling location or station.

3 The number of equipment blanks and trip blanks is based on a fundamental assumption of the number of sampling days each site will require.

4 Field blanks will not be collected as part of this effort; instead, equipment blanks will be collected in the field such that they are subject to both equipment and ambient field contamination.

5 If a second treatment event is necessary, an additional 4 samples will be collected in a second sampling event.

SAP Worksheet #21 — Project Sampling SOP References Table

MQAPP (CH2M HILL, 2007b) Reference numbers refer to the SOP number in the Final Master QAPP, EPR, Vieques, Puerto Rico.

Master SOPs (CH2M HILL, 2010) Reference numbers refer to the SOP number in the Draft Final Master Standard Operating Procedures, Protocols and Plans, Environmental Restoration Program, Vieques, Puerto Rico.

Reference Number	Title, Revision Date and / or Number	Originating Organization of Sampling SOP	Equipment Type	Modified for Project Work? (Y/N)	Comments
Master SOPs, A-2	Soil Sampling	CH2M HILL	Drill rig	Y	Direct push sampling techniques may be used, once the sample tube is split open, follow the split-spoon sampling SOP.
Master SOPs, A-3	Homogenization of Soil and Sediment Samples	CH2M HILL	Sample containers, stainless steel spoons and stainless steel bowls	N	
Master SOPs, A-6	Soil Sampling for VOCs Using the Terra Core Sampler	CH2M HILL	Terra Core Sampler	N	
Master SOPs, A-2	Soil Sampling	CH2M HILL	Split Spoon, Direct Push	N	If needed
Master SOPs, A-2, attachment	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)	ASTM D 2488-00	ASTM document	N	
Master SOPs, A-1	Soil Boring Drilling and Abandonment	CH2M HILL	Drill rig	N	
Master SOPs, B-1	Groundwater Sampling Procedure Low Stress (Low Flow) Purging and Sampling	CH2M HILL	Low Flow pump	N	
Master SOPs, C-1	Calibration and measurement with Field Instruments	CH2M HILL	Multi-parameter groundwater monitoring instrument, PID	N	
Master SOPs, E-1	Decontamination of Personnel and Equipment	CH2M HILL	Decon equipment	N	
Master SOPs, E-2	Decontamination of Drilling Rigs and Equipment	CH2M HILL	Pressure washer	N	
Master SOPs, H-1	Preparing Field Log Books	CH2M HILL	Log book	N	
Master SOPs, H-2	Water Level Measurements	CH2M HILL	Electric water level device	N	
Master SOPs, Master WMP	Master Waste Management Plan	CH2M HILL	Water and soil drums	N	
Master SOPs, H-4	Chain-of-Custody	CH2M HILL	SOP, tape, custody seals, electronic chain of custody forms	N	
Master SOPs, H-5	Packaging and Shipping Procedures for Samples Not Considered Dangerous Goods	CH2M HILL	SOP	N	
Master SOPs, H-6	Equipment Blank Preparation	CH2M HILL	Sample containers	N	
Attachment E	Oxygen Release Compound (ORC) Installation Instructions (Replaceable Filter-Sock Application	Vendor (Regensis)	ORC Socks, rope, winch, stanchion, bolt	N	Manufacturers SOP, manual included as attachment Not included in MQAPP
Attachment F	Operational instructions for persulfate field test kit	Vendor (CHEMetrics)	CHEMet ampouls and sample cup	N	Manufacturers SOP, manual included as attachment Not included in MQAPP

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SAP Worksheet #22 — Field Equipment Calibration, Maintenance, Testing, and Inspection Table

Field Equipment	Calibration Activity	Maintenance Activity	Testing/Inspection Activity	Frequency	Acceptance Criteria	Corrective Action (CA)	Resp. Person	SOP Reference
YSI pH probe	Calibrate probe using YSI Auto-Calibration Standard Solution	Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check	Visual Inspection	Daily, before use	Std X-0.2<Reading<Std X+0.2	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly.	FTL	MQAPP Attachment 1 C-1
YSI Specific conductance Probe	Calibrate probe using YSI Calibration Standard Solution	Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check	Visual Inspection	Daily, before use	±3%	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly.	FTL	MQAPP Attachment 1 C-1
Hach Turbidity Meter	Calibrate probe using Hach-Calibration Standard	Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check	Visual Inspection	Daily, before use	0.1 to 10 NTU standard - ±10%; 11 to 40 NTU standard - ±8%; 41 to 100 NTU standard - ±6.5%; >100 NTU standard - ±5%	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly.	FTL	MQAPP Attachment 1 C-1
YSI Dissolved oxygen and Temperature Probes	Calibrate probe using YSI-Calibration Standard Solution	Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check	During calibration of other probes, check these readings against the day's atmospheric pressure and ambient temperature Check sensor for bubbles and membrane for wrinkles or tear. Visual Inspection	Daily, before use, at the end of the day (if practicable), and when unstable readings occur	±3 mg/L DO of what the tabulated DO is for the measured temperature	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly. Follow manufacturer's instructions to remove bubble or replace torn membrane	FTL	MQAPP Attachment 1 C-1
YSI multi-meter	Calibrate probe using multiple Calibration Standard Solutions	Check mechanical and electronic parts, verify system continuity, check battery, and clean probes. Calibration check.	Visual Inspection	Daily before use, at the end of the day (if practicable), and when unstable readings occur.	Stable readings after 3 minutes pH reads 4.0 +/- 3% conductivity reads 4.49 +/- 3%	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly.	FTL	MQAPP Attachment 1 C-1

SAP Worksheet #22 — Field Equipment Calibration, Maintenance, Testing, and Inspection Table (continued)

Field Equipment	Calibration Activity	Maintenance Activity	Testing/Inspection Activity	Frequency	Acceptance Criteria	Corrective Action (CA)	Resp. Person	SOP Reference
PID	Calibrate using ambient air and isobutylene 100ppm calibration gas	Recharge battery daily	Visual Inspection	Daily, before use, at the end of the day (if practicable), and when unstable readings occur	Ambient air reads 0.0 ppm +/- 3% Isobutylene gas reads 100 ppm +/- 3% ambient air reads 0.0 ppm ±3%: (if possible).	Follow instructions in manual to clean sensor. Do not use this instrument if unable to calibrate properly.	FTL	MQAPP Attachment 1 C-8
ORP	Calibrate using ORP standard solution	Check batteries and have a replacement set on hand	Visual inspection	Daily, before use, at the end of the day (if practicable), and when unstable readings occur	±10 mV of the theoretical redox standard value at that temperature	Clean probe with deionized water and calibrate again. Do not use this instrument if unable to calibrate properly	FTL	MQAPP Attachment C-1
Groundwater sampling pumps and tubing	No calibration required	N/A	Inspect pumps, tubing and air/sample line quick-connects	Regularly	Maintained in good working order per manufacturer's recommendations	Replace items	Field Team Lead	MQAPP Attachment 1 B-1

SAP Worksheet #23 — Analytical SOP References Table

Lab SOP Number	Title, Revision Date, and / or Number	Date Last Revisited if not Revised	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work?[1] (y/n)
100.0003	Sample Preparation of Aqueous Samples by Acid Digestion for ICP, 3/16/09, Rev. 7		Definitive	GW / FMETAL	N/A	Mitkem Laboratories	N
100.0111	Determination of Metals in Water and Soil by Inductively Coupled Argon Plasma Atomic Emission Spectroscopy using Method 6010C, 2/3/09, Rev. 12		Definitive	GW / FMETAL	ICP-AES	Mitkem Laboratories	N
100.0112	pH in Soil Samples by SW-846 9045C and USEPA OLM04.3 and SOM01.2, 1/9/06, Rev. 7	April, 2009	Definitive	SB / WCHEM	pH Meter	Mitkem Laboratories	N
100.0410	Total Organic Carbon in Soil and Solids by Lloyd Kahn Method and SW-846 9060, 12/10/08, Rev. 1		Definitive	SB / WCHEM	TOC Analyzer	Mitkem Laboratories	N
110.0026	Handling Evidentiary Materials, 2/23/06, Rev. 6	April, 2009	N/A	N/A	N/A	Mitkem Laboratories	N
110.0027	Documentation Policy and Procedures, 4/7/08, Rev. 8	April, 2009	N/A	N/A	N/A	Mitkem Laboratories	N
10.0021	Data Report Options, 10/23/08, Rev. 8		N/A	N/A	N/A	Mitkem Laboratories	N
20.0003	Logging Work orders and Samples into Omega ME, 4/9/08, Rev. 3	April, 2009	N/A	N/A	N/A	Mitkem Laboratories	N
30.0002	Bottle Order Preparation, 7/7/08, Rev. 8		N/A	N/A	N/A	Mitkem Laboratories	N
30.0003	Sample Receipt, Storage, Tracking and Disposal, 10/21/08, Rev. 12		N/A	N/A	N/A	Mitkem Laboratories	N
30.0024	Sample and Waste Disposal, 10/21/08, Rev. 8		N/A	N/A	N/A	Mitkem Laboratories	N

SAP Worksheet #23 — Analytical SOP References Table (continued)

Lab SOP Number	Title, Revision Date, and / or Number	Date Last Revisited if not Revised	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work?[1] (y/n)
50.0050	Organic Preparation of Aqueous Samples by Continuous Liquid-Liquid (Method 3520C), 6/30/08, Rev. 3		Definitive	GW / SVOC	N/A	Mitkem Laboratories	N
50.0051	Organic Preparation of Aqueous Samples by Separatory Funnel (Method 3510C), 2/4/08, Rev. 2	April, 2009	Definitive	GW, SPLPS / SVOC	N/A	Mitkem Laboratories	N
50.0052	Organic Preparation of Soil Samples by Sonication (Method 3550B), 2/4/08, Rev. 2	April, 2009	Definitive	SB / SVOC	N/A	Mitkem Laboratories	N
50.0054	Organic Extract Filtration and Concentration Techniques, 2/26/09, Rev. 1		Definitive	SB / SVOC	N/A	Mitkem Laboratories	N
50.0100	Organic Preparation of Soil Samples by Microscale Solvent Extraction (Method 3570), 1/17/08, Rev. 1		Definitive	SB / SVOC	N/A	Mitkem Laboratories	N
50.0053	Organic Preparation of Soil Samples by Soxhlet (Method 3540C), 1/17/08, Rev. 2		Definitive	SB / SVOC	N/A	Mitkem Laboratories	N
100.0003	Sample Preparation of Aqueous Samples by Acid Digestion for ICP, 5/23/06, Rev. 6	1/31/09	Definitive	GW / FMETAL	N/A	Mitkem Laboratories	N
60.0050	Total Petroleum Hydrocarbons by GC-FID using EPA SW-846 Methods 8015/State Methods (DRO, ORO), 2/21/07, Rev. 10	April, 2009	Definitive	SB, GW / TPH	GC/FID	Mitkem Laboratories	N
70.0011	Determination of Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) Analysis by SW846 Method 8270D, 2/21/07, Rev 9	April, 2009	Definitive	GW / SVOC SB / SPLPS	GC/MS	Mitkem Laboratories	Y[4]
SM5310B	Standard Operating Procedure for Total Organic and Inorganic Carbon SW846 9060 SM5310B, Rev. 9, 1/27/09		Definitive	GW / WCHEM	TOC Analyzer	Spectrum Analytical, Inc.	N[3]
90.0038	Gasoline Range Organics by GC/FID using Methods SW-846 8015 and Maine 4.2.17, 1/23/09, Rev. 10		Definitive	SB, GW / TPH	GC/FID	Mitkem Laboratories	N
100.0400	Inorganic Anions by IC EPA 300.0, 2/11/08, Rev. 3	February, 2009	Definitive	SB, GW / WCHEM	IC	Mitkem Laboratories	N
110.0032	ASTM DI Water Leachate Procedure D3987-06, 11/16/07, Rev.0	April, 2009	Definitive	SB / WCHEM	N/A	Mitkem Laboratories	N

SAP Worksheet #23 — Analytical SOP References Table (continued)

Lab SOP Number	Title, Revision Date, and / or Number	Date Last Revisited if not Revised	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work?[1] (y/n)
110.0031	Synthetic Precipitation Leaching Procedure by SW-846 Method 1312, 4/24/09, Rev.4		Definitive	SB / SPLPV, SPLPS	N/A	Mitkem Laboratories	N[2]
70.0033	Determination of Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) Analysis by Selective Ion Monitoring (SIM) Using Modified Method SW-846 8270D, 12/20/07, Rev. 5	April, 2009	Definitive	SB / SVOA	GC/MS	Mitkem Laboratories	N
MI SOP-DNAEXT	Standard Operating Procedure Extraction of DNA from Environmental Samples (Matrix-Water, Soil, BioFilm, Bio-Sep Beads), 1/5/06, Rev. 1.0	May, 2008	Definitive	GW / MICRO	N/A	Microbial Insights	N
MI SOP-PLFA	Standard Operating Procedure Modified Bligh & Dyer Lipid Extraction Matrix (Water, Soil, BioFilm, Bio-Sep Beads), 3/24/09, Rev. 1.2		Definitive	GW / MICRO	N/A	Microbial Insights	N
MI SOP-qPCR	Standard Operating Procedure Quantitative Polymerase Chase Reaction (qPCR), 1/10/06, Rev. 1.0	May, 2008	Definitive	GW / MICRO	PCR System	Microbial Insights	N
90.0012	Determination of Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) Analysis by SW846 Method 8260C, 10/8/08, Rev. 10		Definitive	SB, GW / VOC	GC/MS	Mitkem Laboratories	N

1 If yes, then specify the modification that has been made. Note that any analytical SOP modification made relative to project specific needs must be reviewed and approved by the Navy QAO.

2 Vieques will be considered as "West of the Mississippi" for purposes of choosing an SPLP extraction fluid. This is due to its status as relatively un-industrialized when compared to West and East of the Mississippi River within the continental U.S.

3 TOC analysis is performed in quadruplicate. All four runs and the average are reported in the hardcopy. Only the average is reported in the EDD.

4 Mitkem will modify the method to provide an additional 1ppb calibration standard for aqueous SVOCs.

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SAP Worksheet #24 — Analytical Instrument Calibration Table

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
GC/MS (for VOCs)	Initial Calibration	After major instrument maintenance or when CCV fails	%RSD <20% with a maximum of 10% of the target analytes and/or surrogate compounds allowed %RSD <50%. Relative Retention Times must meet ±0.06 RRT units for each compound and surrogate. Minimum RRFs are suggested in Table 4 of the method (Table 3 of 90.0012).	Check instrument performance, perform corrective maintenance, recalibrate	Mitkem Dept Supervisor	90.0012
	Continuing Calibration	Every 12 hours	%D <20% with a maximum of 20% of the target analytes and/or surrogate compounds allowed %D < 50% D. Minimum RRFs are suggested in Table 4 of the method (Table 3 of 90.0012).	Check instrument performance, perform corrective maintenance, recalibrate and reanalyze all samples analyzed since the last successful calibration verification.		
	BFB Tune	Every 12 hours	Mass - Criteria	Check instrument performance, perform maintenance, retune the instrument and reanalyze tuning solution		
			50 - 15.0-40.0% of mass 95			
			75 - 30.0-60% of mass 95			
			95 - base peak, 100% relative abundance			
			96 - 5.0-9.0% of mass 95			
			173 - less than 2.0% of mass 174			
			174 - greater than 50.0% of mass 95			
			175 - 5.0-9.0% of mass 174			
			176 - 95.0 - 101% of mass 174			
			177 - 5.0-9.0% of mass 176			

SAP Worksheet #24 — Analytical Instrument Calibration Table (continued)

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
GC/MS (for SVOCs and SIM-SVOCs)	Initial Calibration	After major instrument maintenance or when CCV fails	%RSD <20% with a maximum of 10% of the target analytes and/or surrogate compounds allowed %RSD <50%. Relative Retention Times must meet ±0.06 RRT units for each compound and surrogate. Minimum RRFs are suggested in Table 4 of SW-846 8270D.	Check instrument performance, perform corrective maintenance, recalibrate	Mitkem Dept Supervisor	70.0011 70.0033
	Continuing Calibration	Every 12 hours	%D <20% with a maximum of 20% of the target analytes and/or surrogate compounds allowed %D < 50% D. Minimum RRFs are suggested in Table 4 of SW-846 8270D.	Check instrument performance, perform corrective maintenance, recalibrate and reanalyze all samples analyzed since the last successful calibration verification.	Mitkem Dept Supervisor	
	DFTPP Tune	Every 12 hours	Mass - Criteria	Check instrument performance, perform maintenance, retune the instrument and reanalyze tuning solution	Mitkem Dept Supervisor	
			51 - 10-80% of base peak			
			68 - <2.0% of mass 69			
			70 - <2.0% of mass 69			
			127 - 10-80% of base peak			
			197 - <2.0% of mass 198			
			198 - base peak, or >50% of mass 442			
			199 - 5.0-9.0% of mass 198			
			275 - 10-60% of base peak			
			365 - >1% of mass 198			
			441 - present, <24% of mass 442			
			442 - base peak, or >50% of mass 198			
			443 - 15-24% of mass 442			

SAP Worksheet #24 — Analytical Instrument Calibration Table (continued)

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
ICP-AES	Initial Calibration	Every analytical run	Correlation coefficient ≥0.995	Check instrument performance, perform corrective maintenance, recalibrate	Mitkem Dept Supervisor	100.0111
	Continuing Calibration	Every 10 samples and at end of run	All analytes within ±10%	Check instrument performance, perform corrective maintenance, recalibrate and reanalyze all samples analyzed since the last successful calibration verification.		
GC/FID	Initial Calibration	After major instrument maintenance, or when CCV fails	5 point calibration curve for individual compounds, with %Relative Standard Deviation for analyte <20% (GRO) <25% (DRO/ORO)	Check instrument performance, maintenance, recalibrate	Mitkem Dept Supervisor	90.0038 60.0050
	Continuing Calibration	Every 12 hours	%Difference for analyte <20% (GRO) <25% (DRO/ORO)	Check instrument performance, maintenance, recalibrate	Mitkem Dept Supervisor	
pH Meter	Daily Calibration	Each day of use	±0.05 pH units	Use new buffers, recalibrate	Mitkem Dept Supervisor	100.0112
ABI 7300	Initial	Primary – annual	Standard curve R^2 >0.95	Rerun assay / check reagents.	Anita Biernacki	MI SOP-qPCR
	Continuing Calibration Verification	Secondary – every plate (assay)	CT value within 2 units of same point on standard curve	Rerun assay / check reagents.		

SAP Worksheet #24 — Analytical Instrument Calibration Table (continued)

Instrument	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
IC	Initial Calibration	After major instrument maintenance, or when CCV fails	Initial Calibration: 5 point curve with correlation coefficient ≥0.995	Check instrument performance, maintenance, prepare new standards, recalibrate	Mitkem Dept Supervisor	100.0400
	Continuing Calibration	Beginning of run, every 10 samples and at end of run	%Difference < 10%	Check instrument performance, maintenance, recalibrate		
TOC Analyzer	Initial Calibration	Every analytical run	Correlation coefficient ≥0.995	Check instrument performance, perform corrective maintenance, recalibrate	Mitkem Dept Supervisor	SM5310B, 100.0410
	Continuing Calibration	Every 10 samples and at end of run	Total Organic Carbon within ±15%	Check instrument performance, perform corrective maintenance, recalibrate and reanalyze all samples analyzed since the last successful calibration verification.		

1 Specify the appropriate reference letter or number from the Analytical SOP References table (Worksheet #23).

2 Name or title of responsible person may be used.

SAP Worksheet #25 — Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table

Instrument / Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person[2]	SOP Reference[1]
GC/MS	Check for leaks, check gas supply, recondition or replace trap, clean injection port/liner and septa as needed.	Tune (BFB or DFTPP), Continuing Calibration Verification	Monitor instrument performance via tuning mass criteria, and Continuing Calibration Verification	Tune daily, CCV after every 12 hours of operation	Ion abundance within acceptance limits for tune, CCV %D ≤20%	As needed, replace connections, gas line filters, trap, or GC column. Clip column, replace injection port liner, clean injection port, clean source. Repeat tune, calibration or CCV and any affected samples. See Attachment D for more details.	Mitkem Department Supervisor	90.0012 SOP 70.0033
GC/FID	Check for leaks, check gas supply, clean injection port/liner.	Continuing Calibration Verification	Monitor instrument performance via Continuing Calibration Verification	Daily, after every 10 Samples	CCV %D ≤20%	As needed, check GC conditions, check for leaks, clip column, clean/replace injection port/ liner. Repeat calibration or CCV and affected samples. See Attachment 1 of SOP for more details.	Mitkem Department Supervisor	60.0050 90.0038
ICP-AES	Perform leak test, check pump tubing, clean torch and window, clean filters	Initial Calibration Verification and Initial Calibration Blank	Monitor instrument performance via Initial Calibration Verification and Initial Calibration Blank	Daily, after every 10 samples	ICV: all analytes ±10% ICB: no analytes > quantitation limit	Check/replace pump tubing, clean torch and window, clean all filters. Repeat calibration or CCV and any affected samples. See section 6.2 of SOP for more details.	Mitkem Department Supervisor	100.0111
pH Meter	Perform routine calibration check	Calibrate meter with pH 4, and 10 solutions	Monitor instrument performance via pH 7 check	Daily	±0.05 pH unit	Clean electrode, re-fill with solution, replace as necessary. Recalibrate.	Mitkem Department Supervisor	100.0112
TOC Analyzer	Check for leaks, fill humidifier vessel, Replace DI water.	Standard Check sample	Monitor instrument performance via Standard Check sample	Daily, after every 10 samples	Total Organic Carbon within ±15%	Replace catalysts, clean tubing or replace tubing.	Mitkem Department Supervisor	100.0410 SM5310B
IC	Check pressure and eluent supply daily, prime pump	Initial Calibration Verification and ICBlank	Monitor instrument performance via Initial Calibration Verification and ICBlank	Daily, after every 10 samples	All analytes within +/- 10%, no analytes > quantitation limit	Correct the problem and repeat ICV	Mitkem Department Supervisor	100.0400
ABI 7300 (MICRO)	Background check monthly; Dye calibration annually	Initial Calibration Verification and Background check	Monitor instrument performance via Initial Calibration Verification and Blank	Daily, after every 10 samples	Standard curve R^2 value >0.95: CT value within 2 units of same point on standard curve	Clean wells, rerun background assay. See SOP	MI Department Director	MI SOP-qPCR
GC/MS (MICRO)	Check for leaks, check gas supply, recondition or replace trap, clean injection port/liner and septa as needed.	Continuing Calibration Verification	Monitor instrument performance via Continuing Calibration Verification	Daily, after every 10 samples	Total amount of PLFA within field samples must be higher than LMB; serves as a practical quantification limit.	As needed, replace connections, gas line filters, trap, or GC column. Clip column, replace injection port liner, clean injection port, clean source. Repeat tune, calibration or CCV and any affected samples. See Attachment D for more details.	MI Department Director	MI SOP-PLFA

1 Specify the appropriate reference letter or number from the Analytical SOP References table (Worksheet #23).

2 Name or title of responsible person may be used.

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SAP Worksheet #26 — Sample Handling System

SAMPLE COLLECTION, PACKAGING, AND SHIPMENT
Sample Collection (Personnel/Organization): Field Team Leader (Dia Whitaker)/CH2M HILL
Sample Packaging (Personnel/Organization): Sample Processor or Field Team Member (Mike Zamboni)/CH2M HILL
Coordination of Shipment (Personnel/Organization): Sample Processor or Field Team Member (Mike Zamboni)/CH2M HILL
Type of Shipment/Carrier: Overnight/FedEx
SAMPLE RECEIPT AND ANALYSIS
Sample Receipt (Personnel/Organization): Sample Receipt Personnel/Mitkem Laboratories, Inc.; Sample Receipt Personnel/Microbial Insights, Inc. Note that all fractions will be sent to Mitkem with the exception of MICRO analyses, which will be sent directly to Microbial Insights due to holding time concerns.
Sample Custody and Storage (Personnel/Organization): Sample Receipt Personnel/Mitkem Laboratories, Inc.; Sample Receipt Personnel/Microbial Insights, Inc.
Sample Preparation (Personnel/Organization): Extractions Personnel/Mitkem Laboratories, Inc..; Extractions Personnel/Microbial Insights, Inc.
Sample Determinative Analysis (Personnel/Organization): Analytical Personnel/Mitkem Laboratories, Inc.; Analytical Personnel/Mitkem Laboratories, Inc.
SAMPLE ARCHIVING
Field Sample Storage (No. of days from sample collection): 90 days
Sample Extract/Digestate Storage (No. of days from extraction/digestion): Extracts may be disposed of 90 days after extraction.
Microbial; Sample Storage (No. of days from sample collection): 90 days
SAMPLE DISPOSAL
Personnel/Organization: Environmental Health and Safety Office/Mitkem Laboratories, Inc.; Environmental Health and Safety Office/Microbial Insights, Inc.
Number of Days from Analysis: Samples may be disposed of 90 days after report mail date

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SAP Worksheet #27 — Sample Custody Requirements Table

Sample Labeling

Sample labels will include, at a minimum, client name, site, sample ID, date/time collected, analysis group or method, preservative, and sampler's initials. Labels will be taped to the jar to ensure they do not separate. The following exceptions apply:

- Aqueous VOCs: Labels will not be taped onto the 40mL VOA vials because the tape interferes with the laboratory's robotics. Instead, indelible ink will be used on a waterproof label.
- Soil VOCs: Sample vials are pre-weighed; therefore, the laboratory will attach labels to the vials and tape will not be used. Indelible ink will be used on a waterproof label, which will already be affixed to the jar. Sample labels will include, at a minimum, sample ID, date/time collected, preservative, and sampler's initials.

Field Sample Custody Procedures (sample collection, packaging, shipment, and delivery to laboratory)

Samples will be collected by field team members under the supervision of the field team leader. As samples are collected, they will be placed into containers and labeled, as outlined above. Samples will be cushioned with packaging material and placed into coolers containing enough ice to keep the samples below 4°C until they are received by the laboratory. The chain of custody (COC) will also be placed into the cooler. Coolers will be shipped to the laboratory via FedEx, with the airbill number indicated on the COC (to relinquish custody). Upon delivery, the laboratory will log in each cooler and report the status of the samples.

Laboratory Sample Custody Procedures (receipt of samples, archiving, and disposal)

See the laboratory sample handling SOP: 30.0003 "Sample Receipt, Storage, Tracking and Disposal" for details on sample handling. Sample Identification Procedures

Upon opening the cooler, the receiving clerk signs the COC and then takes the temperature using the temperature blank (if absent, then a sample container or infrared thermometer is used). The sample containers in the cooler are unpacked and checked against the client's COC and any discrepancies or breakage is noted on the COC. Next, if any water samples (with the exception of VOC samples) require preservative, the clerk will check the pH values to see if they are in the acceptable pH range. The clerk will deliver the COC (and any other paperwork, e.g., temperature or pH QA notice) to the project manager for LIMS entry and client contact (if needed).

The field logbook will identify the sample ID with the location, depth, date/time collected, and the parameters requested. The laboratory will assign each field sample a laboratory sample ID based on information in the chain of custody. The laboratory will send sample log-in forms to EIS to check sample IDs and parameters are correct.

SAP Worksheet #27 — Sample Custody Requirements Table (continued)

Chain-of-Custody Procedures

Chains of custody will include, at a minimum, laboratory contact information, client contact information, sample information, and relinquished by/received by information. Sample information will include sample ID, date/time collected, number and type of containers, preservative information, analysis method, and comments. The chain of custody will also have the sampler's name and signature. The chain of custody will link location of the sample from the field logbook to the laboratory receipt of the sample. The laboratory will use the sample information to populate the LIMS database for each sample.

SAP Worksheet #28-1 — Laboratory QC Samples Table

Matrix: SB
Analytical Group: VOC
Analytical Method / SOP Reference: SW-846 8260C / 90.0012

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. No samples may be run until an acceptable method blank has been run.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS.	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable reprep the samples and QC. Check standard prep. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS

SAP Worksheet #28-1 — Laboratory QC Samples Table (continued)

Matrix: SB
Analytical Group: VOC
Analytical Method / SOP Reference: SW-846 8260C / 90.0012

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples. If similar results, report both runs. Flag outliers with an * on Form 8.	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	4 Per Sample	1,2-Dichloroethane-d4 65-128% Bromofluorobenzene 77-111% Dibromofluoromethane 65-132% Toluene-d8 85-115% 1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.	If sample volume available, reanalyze. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/bias	1,2-Dichloroethane-d4 65-128% Bromofluorobenzene 77-111% Dibromofluoromethane 65-132% Toluene-d8 85-115% 1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.

SAP Worksheet #28-2 — Laboratory QC Samples Table

Matrix: SB
Analytical Group: SVOC
Analytical Method / SOP Reference: SW-846 8270D / 70.0011

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2 QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2 QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS.	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS

SAP Worksheet #28-2 — Laboratory QC Samples Table (continued)

Matrix: SB
Analytical Group: SVOC
Analytical Method / SOP Reference: SW-846 8270D / 70.0011

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples, if similar results report both runs. Flag outliers with an * on Form 8	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	1 Per Sample	Benzo(e)pyrene-d12 45-135% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.	If sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Benzo(e)pyrene-d12 45-135% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.

SAP Worksheet #28-3 — Laboratory QC Samples Table

Matrix: SB

Analytical Group: SPLPV

Analytical Method / SOP Reference: SW-846 1312, 8260C / 110.0031, 90.0012

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. No samples may be run until an acceptable method blank has been run.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS.	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS.
Matrix Spike	If deemed necessary by the laboratory.	Same as LCS.	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable reprep the samples and QC. Check standard prep. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS.

SAP Worksheet #28-3 — Laboratory QC Samples Table (continued)

Matrix: SB

Analytical Group: SPLPV

Analytical Method / SOP Reference: SW-846 1312, 8260C / 110.0031, 90.0012

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike Duplicate	If deemed necessary by the laboratory.	Same as MS	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples. If similar results, report both runs. Flag outliers with an * on Form 8.	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	4 Per Sample	1,2-Dichloroethane-d4 65-128% Bromofluorobenzene 77-111% Dibromofluoromethane 65-132% Toluene-d8 85-115% 1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.	If sample volume available, reanalyze. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/bias	1,2-Dichloroethane-d4 65-128% Bromofluorobenzene 77-111% Dibromofluoromethane 65-132% Toluene-d8 85-115% 1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.

SAP Worksheet #28-4 — Laboratory QC Samples Table

Matrix: SB
Analytical Group: SPLPS
Analytical Method / SOP Reference: SW-846 1312, 8270D / 110.0031, 70.0011

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2 QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2 QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix Spike	If deemed necessary by the laboratory.	Same as LCS	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS

SAP Worksheet #28-4 — Laboratory QC Samples Table (continued)

Matrix: SB
Analytical Group: SPLPS
Analytical Method / SOP Reference: SW-846 1312, 8270D / 110.0031, 70.0011

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike Duplicate	If deemed necessary by the laboratory.	Same as MS	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples, if similar results report both runs. Flag outliers with an * on Form 8	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	3 Per Sample	2-Fluorobiphenyl 45-105% Nitrobenzene-d5 35-100% Terphenyl-d14 30-125% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.	If sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	2-Fluorobiphenyl 45-105% Nitrobenzene-d5 35-100% Terphenyl-d14 30-125% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.

SAP Worksheet #28-5 — Laboratory QC Samples Table

Matrix: SB
Analytical Group: WCHEM
Analytical Method / SOP Reference: EPA 300.0, SW-846 9045C, Lloyd Kahn / 100.0400, 100.0112, 100.00410

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Nitrate (EPA 300.0)						
Method Blank	One per batch	< QL	Investigate source of contamination. Rerun method blank.	Analyst, Laboratory Supervisor	Bias/Contamination	< QL
Laboratory Control Sample (LCS)	One per batch of 20 or fewer samples	See Worksheet 15	Reanalyze. Investigate standards and recalibrate if necessary.	Analyst, Laboratory Supervisor	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as LCS
Matrix Spike	One per batch	Same as LCS	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	One per batch	Same as MS	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as MS
pH (SW-846 9045C)						
Laboratory Replicate	One per batch	%RPD ≤20%	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy, Bias	%RPD ≤20%

SAP Worksheet #28-5 — Laboratory QC Samples Table (continued)

Matrix: SB
Analytical Group: WCHEM
Analytical Method / SOP Reference: EPA 300.0, SW-846 9045C, Lloyd Kahn / 100.0400, 100.0112, 100.00410

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Total Organic Carbon (Lloyd Kahn)						
Method Blank	One per batch	< QL	Investigate source of contamination. Rerun method blank.	Analyst, Laboratory Supervisor	Bias/Contamination	< QL
Laboratory Control Sample (LCS)	One per batch of 20 or fewer samples	See Worksheet 15	Reanalyze. Investigate standards and recalibrate if necessary.	Analyst, Laboratory Supervisor	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as LCS
Laboratory Quadruplicate	One per batch	%RSD ≤20%	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Precision	%RSD ≤20%

SAP Worksheet #28-6 — Laboratory QC Samples Table

Matrix: GW
Analytical Group: VOC
Analytical Method / SOP Reference: SW-846 8260C / 90.0012

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2 QL	Investigate source of contamination. Rerun method blank. No samples may be run until an acceptable method blank has been run.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2 QL
LCS	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL, narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix Spike	If deemed necessary by the laboratory.	Same as LCS	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable, reprep the samples and QC. Check standard prep. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	If deemed necessary by the laboratory.	Same as MS	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples. If results are similar, report both runs. Flag outliers with an * on Form 8	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	4 Per Sample	1,2-Dichloroethane-d4 70-120%Bromofluorobenzene 75-120%Dibromofluoromethane 85-115%Toluene-d8 85-120%1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.	If sample volume available, reanalyze. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	1,2-Dichloroethane-d4 70-120%Bromofluorobenzene 75-120%Dibromofluoromethane 85-115%Toluene-d8 85-120%1 out allowed if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference.

SAP Worksheet #28-7 — Laboratory QC Samples Table

Matrix: GW
Analytical Group: SVOC
Analytical Method / SOP Reference: SW-846 8270D / 70.0011

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2 QL; 5X QL for bis(2-ethylhexyl)phthalate	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2 QL; 5X QL for bis(2-ethylhexyl)phthalate
LCS	One per prep batch of twenty or fewer samples of similar matrix	See Worksheet 15	Reanalyze once. If the LCS recoveries are high but the sample results are <QL, narrate. Flag with * on Form 3. LCS exceedances may indicate the need to recalibrate as described in Worksheet #24	Analyst, Supervisor, QA Manager	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix Spike	If deemed necessary by the laboratory.	Same as LCS	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable, check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	If deemed necessary by the laboratory.	Same as MS	Same as MS.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS
Internal Standards (IS)	Each field and QC sample	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.	Reanalyze affected samples. If similar results, report both runs. Flag outliers with an * on Form 8.	Analyst	Accuracy	IS area -50% to +100% compared to IS from CV; IS RT window ±0.5 minutes compared to CV RT.
Surrogates	3 Per Sample	2-Fluorobiphenyl 50-110% Nitrobenzene-d5 40-110% Terphenyl-d14 50-135% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.	If sample volume available, re-extract. Report both if second successful analysis is outside of Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	2-Fluorobiphenyl 50-110% Nitrobenzene-d5 40-110% Terphenyl-d14 50-135% 1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery.

SAP Worksheet #28-8 — Laboratory QC Samples Table

Matrix: GW, SW
Analytical Group: FMETAL
Analytical Method / SOP Reference: SW-846 6010C / 100.0111

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Method Blank	One per batch	<1/2 QL	Investigate contamination. Redigest and reanalyze, if sample concentration is >10X blank concentration narrate.	Analyst, Laboratory Supervisor	Bias/Contamination	<1/2 QL
Laboratory Control Sample (LCS)	One per batch of 20 or fewer samples	See Worksheet 15	Redigest and reanalyze. Narrate if recovery is high and sample is <QL.	Analyst, Laboratory Supervisor	Accuracy, Precision	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as LCS
Matrix spike	If deemed necessary by the laboratory.	See Worksheet 15; 80-120%R if sample < 4X spike value	No corrective action required. Mitkem performs post-digestion spike analysis, evaluates using ±25%, and qualifies affected elements with an N flag in associated samples.	Analyst, Laboratory Supervisor	Accuracy	See Worksheet 15; 80-120%R if sample < 4X spike value
Matrix Spike Duplicate	If deemed necessary by the laboratory.	Same as MS	Same as MS	Analyst, Laboratory Supervisor	Accuracy, Precision	Same as MS
Laboratory Replicate	One per 20 field samples	%RPD ≤20% for results >5X QL	Qualify affected elements with an * flag in associated samples	Analyst, Laboratory Supervisor	Precision	%RPD ≤20% for results >5X QL
Serial Dilution	One per 20 field samples	%D ±10%	Qualify affected elements with an E flag in associated samples	Analyst, Laboratory Supervisor	Accuracy/Bias, Precision	If original sample result is at least 50x MDL, 5-fold dilution must agree within ±10% of the original result.

SAP Worksheet #28-9 — Laboratory QC Samples Table

Matrix: GW
Analytical Group: MICRO
Analytical Method / SOP Reference: PLFA, qPCR / MI SOP-PLFA, MI SOP-qPCR

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
qPCR by MI SOP-qPCR						
Assay Negative Control (Blank)	1 per analytical assay plate	Values for positive samples are set above any fluorescence for the negative control.	Rerun assay; may have to reoptimize assay.	Anita Biernacki	Accuracy/Bias, Contamination	Values for positive samples are set above any fluorescence for the negative control.
DNA extraction negative control	1 per analytical batch	CT ≤ Assay Negative Control	Rerun assay or reextract samples if problem persists	Anita Biernacki	Accuracy/Bias	CT ≤ Assay Negative Control
Positive Control	1 per analytical assay plate	CT value within 2 units of same point on standard curve	Rerun assay / check reagents	Anita Biernacki	Accuracy/Bias	CT value within 2 units of same point on standard curve
PLFA by MI SOP-PLFA						
Laboratory Method Blank (LMB)	Once per event or every ten samples whichever more frequent	Total amount of PLFA within field samples must be higher than LMB; serves as a practical quantification limit.	Field samples below our LMB are reported below our practical quantification limit.	Susan Lewis	Accuracy/Bias, Contamination	Total amount of PLFA within field samples must be higher than LMB; serves as a practical quantification limit.

SAP Worksheet #28-10 — Laboratory QC Samples Table

Matrix: GW

Analytical Group: WCHEM

Analytical Method / SOP Reference: EPA 300.0, SM5310B / 100.0025, SM5310B

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Nitrate, Sulfate (EPA 300.0)						
Method Blank	One per batch	< QL	Investigate source of contamination. Rerun method blank.	Analyst, Laboratory Supervisor	Bias/Contamination	< QL
Laboratory Control Sample (LCS)	One per batch of 20 or fewer samples	See Worksheet 15	Reanalyze. Investigate standards and recalibrate if necessary.	Analyst, Laboratory Supervisor	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as LCS
Matrix Spike	If deemed necessary by the laboratory	Same as LCS	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	If deemed necessary by the laboratory	Same as MS	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as MS

SAP Worksheet #28-10 — Laboratory QC Samples Table (continued)

Matrix: GW

Analytical Group: WCHEM

Analytical Method / SOP Reference: EPA 300.0, SM5310B / 100.0025, SM5310B

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Total Organic Carbon						
Method Blank	One per batch	< QL	Investigate source of contamination. Rerun method blank.	Analyst, Laboratory Supervisor	Bias/Contamination	< QL
Laboratory Control Sample (LCS)	One per batch of 20 or fewer samples	See Worksheet 15	Reanalyze. Investigate standards and recalibrate if necessary.	Analyst, Laboratory Supervisor	Accuracy/Bias	See Worksheet 15
Laboratory Control Sample Duplicate (LCSD)	If no MSD in batch	Same as LCS	Same as LCS	Analyst, Laboratory Supervisor	Accuracy, Bias, Precision	Same as LCS. %RPD < 20%
Laboratory Duplicate	One per batch	%RSD ≤20%	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Precision	%RSD ≤20%
Matrix Spike	If deemed necessary by the laboratory	Same as LCS	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy/Bias	Same as LCS

SAP Worksheet #28-11 — Laboratory QC Samples Table

Matrix: SB

Analytical Group: GRO

Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
TPH-GRO						
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	80-120% Recovery	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	80-120% Recovery
Laboratory Control Sample Duplicate (LCSD)	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS and < 20% RPD	Reanalyze once. If the LCS recoveries are within QC limits, narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as LCS and < 20% RPD
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS	If recoveries are outside limits and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS

SAP Worksheet #28-11 — Laboratory QC Samples Table (continued)

Matrix: SB

Analytical Group: GRO

Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS and < 20% RPD	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS and < 20% RPD
Surrogates	1 Per Sample	Bromofluorobenzene 79-118%	Unless obvious chromatographic interference, if sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Bromofluorobenzene 79-118%
TPH-DRO, TPH-ORO						
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	60-140% Recovery	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	60-140% Recovery
Laboratory Control Sample Duplicate (LCSD)	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS and < 20% RPD	Reanalyze once. If the LCS recoveries are within QC limits, narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as LCS and < 20% RPD

SAP Worksheet #28-11 — Laboratory QC Samples Table (continued)

Matrix: SB

Analytical Group: GRO

Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS and < 20% RPD	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS and < 20% RPD
Surrogates	2 Per Sample	5a-Androstane 58-115% Orthoterphenyl 50-150%	Unless obvious chromatographic interference, if sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	5a-Androstane 58-115% Orthoterphenyl 50-150%

SAP Worksheet #28-12 — Laboratory QC Samples Table

Matrix: GW

Analytical Group: GRO

Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
TPH-GRO						
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	80-120% Recovery	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	80-120% Recovery
Laboratory Control Sample Duplicate (LCSD)	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS and < 20% RPD	Reanalyze once. If the LCS recoveries are within QC limits, narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as LCS and < 20% RPD
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS	If recoveries are outside limits and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS

SAP Worksheet #28-12 — Laboratory QC Samples Table (continued)

Matrix: GW						
Analytical Group: GRO						
Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038						
QC Sample	**Frequency / Number**	**Method / SOP QC Acceptance Limits**	**Corrective Action**	**Person(s) Responsible for Corrective Action**	**Data Quality Indicator (DQI)**	**Measurement Performance Criteria**
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS and < 20% RPD	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS and < 20% RPD
Surrogates	1 Per Sample	Bromofluorobenzene 80-120%	Unless obvious chromatographic interference, if sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	Bromofluorobenzene 80-120%
TPH-DRO, TPH-ORO						
Method Blank	One per prep batch of twenty or fewer samples of similar matrix	< 1/2QL	Investigate source of contamination. Rerun method blank. Re-extract associated batch of samples unless ND for the contaminant.	Analyst, Supervisor, QA Manager	Accuracy/Bias, Contamination	< 1/2QL
Laboratory Control Sample (LCS)	One per prep batch of twenty or fewer samples of similar matrix	60-140% Recovery	Reanalyze once. If the LCS recoveries are high but the sample results are <QL narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	60-140% Recovery
Laboratory Control Sample Duplicate (LCSD)	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS and < 20% RPD	Reanalyze once. If the LCS recoveries are within QC limits, narrate. Flag with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as LCS and < 20% RPD

SAP Worksheet #28-12 — Laboratory QC Samples Table (continued)

Matrix: GW

Analytical Group: GRO

Analytical Method / SOP Reference: SW-846 8015M / 60.0050, 90.0038

QC Sample	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS	If recoveries are outside limits and surrogate and LCS criteria are met, note in narrative. If both the LCS and MS/MSD are unacceptable check standard prep. Speak with PM regarding further action. Flag outliers with * on Form 3	Analyst, Supervisor, QA Manager	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS and < 20% RPD	Same as MS	Analyst, Supervisor, QA Manager	Accuracy/Bias, Precision	Same as MS and < 20% RPD
Surrogates	2 Per Sample	5a-Androstane 80-120% Orthoterphenyl 80-120%	Unless obvious chromatographic interference, if sample volume available, re-extract. Report both if second successful analysis is outside Holding Time or both fail QC criteria. Flag with * on Form 2.	Analyst, Supervisor, QA Manager	Accuracy/Bias	5a-Androstane 80-120% Orthoterphenyl 80-120%

SAP Worksheet #29 — Project Documents and Records Table

Document	Where Maintained
Field Notebooks	Electronic .pdf copies in the project file. Hardcopy (bound notebook) in the project file. Archived at project closeout*.
Chain-of-Custody Records	Electronic .pdf copies in the project file. Hardcopy in the project file. Archived at project closeout.
Air Bills	Hardcopy in the project file. Archived at project closeout.
Telephone Logs	Hardcopy in the project file. Archived at project closeout.
Corrective Action Forms	Electronic .pdf copies in the project file. Hardcopy in the project file. Archived at project closeout.
PID/FID readings	Recorded in Field Notebook. Stored in VDMS.
Water quality field parameters collected during groundwater sampling	Recorded in Field Notebook. Stored in VDMS.
OVM/OVA readings	Recorded in Field Notebook. Stored in VDMS.
Various field measurements	Recorded in Field Notebook.
All field equipment calibration information	Recorded in Field Notebook.
Pertinent telephone conversations	Recorded in Field Notebook.
Field equipment maintenance records	Inspected by Field Team Leader. Not maintained.
Sample Receipt, Custody, and Tracking Records	Electronic .pdf copies in the project file. Hardcopy in the full data package.
Equipment Calibration Logs	Hardcopy in the full data package[1]. Archived at project closeout.
Sample Prep Logs	Hardcopy in the full data package[1]. Archived at project closeout.
Run Logs	Hardcopy in the full data package[1]. Archived at project closeout.
Reported Field Sample Results	Electronic .pdf copies in the project file. Hardcopy in the full data package[1]. Archived at project closeout.
Reported Results for Standards, QC Checks, and QC Samples	Hardcopy in the full data package[1]. Archived at project closeout.
Instrument Printouts (raw data) for Field Samples, Standards, QC Checks, and QC Samples	Hardcopy in the full data package[1]. Archived at project closeout.
Sample Disposal Records	Maintained by the laboratory.
Extraction/Clean-up Records	Hardcopy in the full data package[1].
Raw Data	Hardcopy in the full data package[1]. Archived at project closeout.
Field Sampling Audit Checklists	Hardcopy in the project file. Archived at project closeout.
Fixed Laboratory Audit Checklists	If completed, hardcopy in the project file. Archived at project closeout.
Data Validation Reports	Electronic .pdf copies in the project file. Hardcopy stored with the data package. Archived at project closeout.
Vieques ERP Master Health and Safety Plan	Hardcopy in office and field
AOC E and I Site Specific HASP	Hardcopy in office and field
Manual Integration Documentation	Hardcopy in the full data package. Archived at project closeout.
Pilot Study Progress Tech Memos and Study Report	Electronic .pdf copies in the project file. Hardcopy (bound notebook) in the project file. Archived at project closeout*.

* Data archiving will be done in accordance with Navy requirements. CH2M HILL will provide the Navy (currently Bonnie Capito) all data and reports for archiving.

1 The format of the full hardcopy data package is described in Mitkem SOP 10.0021. CH2M HILL requires a “Level 4” package..

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SAP Worksheet #30 — Analytical Services Tables

Matrix	Analytical Group	Sample Locations/ID Number	Analytical Method	Data Package Turnaround Time	Laboratory / Organization[1] (name and address, contact person, and telephone number)	Backup Laboratory / Organization (name and address, contact person, and telephone number)
SB[3]	VOC	8	VOCs by SW-846 8260C	28 Calendar-day TAT	Mitkem Laboratories, Division of Spectrum Analytical 175 Metro Center Blvd Warwick, RI 02886 Ed Lawler (401) 732-3400	PEL Laboratories, Division of Spectrum Analytical 8405 Benjamin Road Tampa, FL 33634 John Heyman (813) 888-9507
SB[3]	SVOC	8	SVOCs by SW-846 8270D			
SB[3]	TPH	8	TPH-GRO, TPH-DRO, TPH-ORO by SW846 8015M			
SB[3]	SPLPV	8	SPLPV by SW-846 1312, 8260C			
SB[3]	SPLPS	8	SPLPS by SW-846 1312, 8270D			
SB[3]	WCHEM	2	Nitrate by EPA 300.0 pH by SW-846 9045C Total Organic Carbon (TOC) by Lloyd Kahn			Spectrum Laboratories 11 Almgren Drive Agawam, MA 01001 Dulce Litchfield (413) 789-9018
GW	VOC	27 – 31	VOCs by SW-846 8260C	28 Calendar-day TAT	Mitkem Laboratories, Division of Spectrum Analytical 175 Metro Center Blvd Warwick, RI 02886 Ed Lawler (401) 732-3400	PEL Laboratories, Division of Spectrum Analytical 8405 Benjamin Road Tampa, FL 33634 John Heyman (813) 888-9507
GW	SVOC	27 – 31	SVOCs by SW-846 8270D			
GW	TPH	27 – 31	TPH-GRO, TPH-DRO, TPH-ORO by SW846 8015M			
GW	FMETAL	27 – 31	FMETALs by SW-846 6010C			
GW	WCHEM	27 – 31	Sulfate and Nitrate by EPA 300.0			Spectrum Laboratories 11 Almgren Drive Agawam, MA 01001 Dulce Litchfield (413) 789-9018
			Total Organic Carbon (TOC) by SM5310B	28 Calendar-day TAT	Spectrum Laboratories 11 Almgren Drive Agawam, MA 01001 Dulce Litchfield (413) 789-9018	Mitkem Laboratories, Division of Spectrum Analytical 175 Metro Center Blvd Warwick, RI 02886 Ed Lawler (401) 732-3400
GW	MICRO	3 – 4	PLFA by MI SOP-PLFA Naphthalene Dioxygenase (NAH) by MI SOP-qPCR Benzyl Succinate Synthase (bssA) by MI SOP-qPCR	28 Calendar-day TAT	Microbial Insights 2340 Stock Creek Blvd Rockford, TN 37853 Anita Biernacki (865) 573-8188	TBD[2]

1 If the laboratory is not known at time of SAP submission, put "TBD" in the column as a placeholder.

2 Due to the non-routine nature of microbial analyses, a backup laboratory has not been selected. This is to be determined pending the need to do so.

3 If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2). Worksheet sample numbers represent a single event.

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SAP Worksheet #31 — Planned Project Assessments Table

Assessment Type	Frequency	Internal or External	Organization Performing Assessment	Person(s) Responsible for Performing Assessment (title and organizational affiliation)	Person(s) Responsible for Responding to Assessment Findings (title and organizational affiliation)	Person(s) Responsible for Identifying and Implementing Corrective Actions (CA) (title and organizational affiliation)	Person(s) Responsible for Monitoring Effectiveness of CA (title and organizational affiliation)
Field Performance Audit	One during sampling activities	Internal	CH2M HILL	Stephen Brand PM CH2M HILL	Project Field Team CH2M HILL	John Swenfurth PM CH2M HILL	Brett Doerr Environmental Manager CH2M HILL
Safe Work Observation	One per week during field activities	Internal	CH2M HILL	Dia Whitaker, or any team member SSC CH2M HILL	Project Field Team CH2M HILL	Mark Orman H & S Officer CH2M HILL	Stephen Brand PM CH2M HILL

Note: Analytical laboratory audits by the contractor are not project-specific, but are done on a Navy CLEAN program-wide basis. However, the laboratory is subject to audits due to NFESC evaluation and will also be subject to audits due to DoD ELAP acceptance during the project timeframe.

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SAP Worksheet #32 — Assessment Findings and Corrective Action Responses

Assessment Type	Nature of Deficiencies Documentation	Individual(s) Notified of Findings (name, title, organization)	Timeframe of Notification	Nature of Corrective Action (CA) Response Documentation	Individual(s) Receiving CA Response (name, title, organization)	Timeframe for Response
Field Performance Audit	Field Performance Audit Checklist	Field Team PM Environmental Manager	Within one day of audit	Verbal and CA Form	FTL CH2M HILL	Within one day of receipt of CA Form
Safe Work Observation (SWO)	Safe Work Observation Form	FTL Field Team PM	Immediately (person involved or observed person). Following day (field team). Within 1 week if worthy of elevation (H&S officer)	On SWO Form	FTL and individual being observed, and the PM and if elevated to the H&S officer.	Corrected in the field immediately, and within 1 week if elevated.

SAP Worksheet #32-1 — Corrective Action Form

Person initiating CA _____ **Date** _____

Description of problem and when identified: _____

_____

_____

_____

_____

Cause of problem, if known or suspected: _____

_____

_____

_____

<u>Sequence of CA:</u> (including date implemented, action planned and personnel/data affected)

_____

_____

_____

_____

_____

_____

_____

_____

CA implemented by: _____ **Date:** _____

CA initially approved by: _____ **Date:** _____

Follow-up date: _____

Final CA approved by: _____ **Date:** _____

Information copies to:

_____

_____

_____

_____

SAP Worksheet #32-2 — Field Performance Audit Checklist

Project Responsibilities

Project No.: _____ **Date:** _____

Project Location: _____ **Signature:** _____

Team Members

Yes _____ No _____ 1) Is the approved work plan being followed?
Comments

Yes _____ No _____ 2) Was a briefing held for project participants?
Comments

Yes _____ No _____ 3) Were additional instructions given to project participants?
Comments

Sample Collection

Yes _____ No _____ 1) Is there a written list of sampling locations and descriptions?
Comments

Yes _____ No _____ 2) Are samples collected as stated in the Master SOPs?
Comments

Yes _____ No _____ 3) Are samples collected in the type of containers specified in the work plan?
Comments

Yes _____ No _____ 4) Are samples preserved as specified in the work plan?
Comments

Yes _____ No _____ 5) Are the number, frequency, and type of samples collected as specified in the work plan?
Comments

SAP Worksheet #32-2 — Field Performance Audit Checklist (continued)

Yes _____ No _____ 6) Are QA checks performed as specified in the work plan?
Comments

Yes _____ No _____ 7) Are photographs taken and documented?
Comments

Document Control

Yes _____ No _____ 1) Have any accountable documents been lost?
Comments

Yes _____ No _____ 2) Have any accountable documents been voided?
Comments

Yes _____ No _____ 3) Have any accountable documents been disposed of?
Comments

Yes _____ No _____ 4) Are the samples identified with sample tags?
Comments

Yes _____ No _____ 5) Are blank and duplicate samples properly identified?
Comments

Yes _____ No _____ 6) Are samples listed on a chain-of-custody record?
Comments

Yes _____ No _____ 7) Is chain-of-custody documented and maintained?
Comments

SAP Worksheet #32-3 — Safe Work Observation Form

Project:		**Observer:**	**Date:**
Position/Title of worker observed:		**Background Information/comments:**	
Task/Observation Observed:			

- Identify and reinforce safe work practices/behaviors
- Identify and improve on at-risk practices/acts
- Identify and improve on practices, conditions, controls, and compliance that eliminate or reduce hazards
- Proactive PM support facilitates eliminating/reducing hazards (do you have what you need?)
- Positive, corrective, cooperative, collaborative feedback/recommendations

Actions & Behaviors	Safe	At-Risk	Observations/Comments
Current & accurate Pre-Task Planning/Briefing (Project safety plan, STAC, AHA, PTSP, tailgate briefing, etc., as needed)			**Positive Observations/Safe Work Practices:**
Properly trained/qualified/experienced			
Tools/equipment available and adequate			
Proper use of tools			**Questionable Activity/Unsafe Condition Observed:**
Barricades/work zone control			
Housekeeping			
Communication			
Work Approach/Habits			
Attitude			
Focus/attentiveness			**Observer's CAs/Comments:**
Pace			
Uncomfortable/unsafe position			
Inconvenient/unsafe location			
Position/Line of fire			
Apparel (hair, loose clothing, jewelry)			
Repetitive motion			**Observed Worker's CAs/Comments:**
Other…			

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SAP Worksheet #33 — QA Management Reports Table

Type of Report	Frequency (daily, weekly, monthly, quarterly, annually, etc.)	Projected Delivery Date(s)	Person(s) Responsible for Report Preparation (title and organizational affiliation)	Report Recipient(s) (title and organizational affiliations)
Field Audit Report	One during sampling activities	Submitted with report in which data are analyzed and presented	Project Manager: John Swenfurth/CH2M HILL	Regional Health, Safety, Environment, and Quality Manager: Mark Orman/CH2M HILL Environmental Manager: Brett Doerr/CH2M HILL Included in project files.
Data Validation Reports	Once, after analysis by laboratory, for all laboratory analytical data except WCHEM and MICRO analyses.	Submitted by the data validator within 21 calendar-days of receipt of analytical data (from laboratory)	Project Manager: Laura Maschoff/DataQual	Project Chemist: Michael Zamboni/CH2M HILL Project EIS: Emma Brower/CH2M HILL Project Manager: John Swenfurth/CH2M HILL
Data Usability Assessments (Data Quality Evaluation)	Once, as an appendix to the report in which data are analyzed and presented.	Along with the project report.	Project Chemist: Michael Zamboni/CH2M HILL	Vieques RPM: Daniel Rodriquez/USEPA and Vieques RPM Wilmarie Rivera/PREQB

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SAP Worksheet #34 — Verification (Step I) Process Table

Verification Input	Description	Internal / External	Responsible for Verification (name, organization)
Field Notebooks	Field notebooks will be reviewed internally and placed into the project file for archival at project closeout.	Internal	Project Manager: John Swenfurth/CH2M HILL
Chains of Custody and Shipping Forms	Chain-of-custody forms and shipping documentation will be reviewed internally upon their completion and verified against the packed sample coolers they represent. The shipper's signature on the chain-of-custody will be initialed by the reviewer, a copy of the chain-of-custody retained in the site file, and the original and remaining copies taped inside the cooler for shipment.	Internal	Field Team Leader (Stephen Brand and Kenji Butler)/CH2M HILL Project EIS: Emma Brower/CH2M HILL
Sample Condition upon Receipt	Any discrepancies, missing, or broken containers will be communicated to the project EIS in the form of laboratory logins.	Internal	Project EIS: Emma Brower/CH2M HILL
Sample Chronology	Holding times from collection to extraction or analysis and from extraction to analysis will be considered by the data validator during the data validation process.	External	Data Validation Subcontractor: Laura Maschoff/DataQual
Documentation of Laboratory Method Deviations	Laboratory Method Deviations will be discussed and approved by the project chemist. Documentation will be incorporated into the case narrative which becomes part of the final hardcopy data package.	Internal	Project Chemist: Michael Zamboni/CH2M HILL
Electronic Data Deliverables	Electronic Data Deliverables will be compared against hardcopy laboratory results (10% check).	Internal	Project EIS: Emma Brower/CH2M HILL
Case Narrative	Case narratives will be reviewed by the data validator during the data validation process.100 percent of the VOC, SVOC, SPLPV, and SPLPS data will undergo third party validation. The remaining fractions (MICRO, FMETAL, and WCHEM) will not undergo third-party validation and will instead undergo an internal evaluation as detailed by Worksheet 36. Of the data that are third-party validated, the data validator will choose 10 percent of the data points to recalculate from the raw data in order to verify calculations.	External	Data Validation Subcontractor: Laura Maschoff/DataQual
Laboratory Data	All laboratory data packages will be verified internally by the laboratory performing the work for completeness and technical accuracy prior to submittal. Received data packages will be verified externally by the third party validator. 100 percent of the VOC, SVOC, SPLPV, and SPLPS data will undergo third party validation. The remaining fractions (MICRO, FMETAL, and WCHEM) will not undergo third-party validation and will instead undergo an internal evaluation as detailed by Worksheet 36. Of the data that are third-party validated, the data validator will choose 10 percent of the data points to recalculate from the raw data in order to verify calculations. Also, the data will be verified for completeness by an Environmental Information System (EIS) specialist. A chemist will perform a data quality evaluation.	Internal and External	Respective Laboratory QA Officer Data Validation Subcontractor: Laura Maschoff/DataQual Project EIS: Emma Brower/CH2M HILL Project Chemist: Michael Zamboni/CH2M HILL

SAP Worksheet #34 — Verification (Step I) Process Table (continued)

Verification Input	Description	Internal / External	Responsible for Verification (name, organization)
Audit Reports	Upon report completion, a copy of all audit reports will be placed in the site file. If corrective actions are required, a copy of the documented corrective action taken will be attached to the appropriate audit report in the QA site file. Periodically, and at the completion of site work, site file audit reports and corrective action forms will be reviewed internally to ensure that all appropriate corrective actions have been taken and that corrective action reports are attached. If corrective actions have not been taken, the site manager will be notified to ensure action is taken.	Internal	Project Manager: John Swenfurth/CH2M HILL Project Chemist: Michael Zamboni/CH2M HILL
Corrective Action Reports	Corrective action reports will be reviewed by the project chemist or project manager and placed into the project file for archival at project closeout.	Internal	Project Chemist: Michael Zamboni/CH2M HILL Project Manager: John Swenfurth/CH2M HILL

SAP Worksheet #35 — Validation (Steps IIa and IIb) Process Table

Step IIa / IIb[1]	Validation Input	Description	Responsible for Validation (name, organization)
IIa	Laboratory Methods	Ensure the laboratory analyzed samples using the correct methods.	Project Chemist: Michael Zamboni/CH2M HILL
IIa	Target Compound List and Target Analyte List	Ensure the laboratory reported all analytes from each analysis group unless a site-specific requirement dictates a different list.	Project Chemist: Michael Zamboni/CH2M HILL
IIb	Reporting Limits	Ensure the laboratory met the project-designated quantitation limits. If quantitation limits were not met, the reason will be determined and documented.	Project Chemist: Michael Zamboni/CH2M HILL
IIa	Field SOPs	Ensure that all field SOPs were followed.	Field Team Leader: Kenji Butler and Stephen Brand/CH2M HILL
IIa	Laboratory SOPs	Ensure that approved analytical laboratory SOPs were followed.	Respective Laboratory Quality Assurance Officer
IIa	Raw Data	10 percent review of raw data to confirm laboratory calculations.	Data Validation Subcontractor: Laura Maschoff/DataQual
IIb	Onsite Screening	All non-analytical field data will be reviewed against QAPP requirements for completeness and accuracy based on the field calibration records.	Field Team Leader: Kenji Butler and Stephen Brand/CH2M HILL
IIa	Documentation of Method QC Results	Establish that all required method QC samples were run.	Data Validation Subcontractor: Laura Maschoff/DataQual
IIb	Documentation of field QC Sample Results	Establish that all required field QC samples were run.	EIS: Emma Brower/CH2M HILL Project Chemist: Michael Zamboni/CH2M HILL
IIb	NFESC Evaluation	Ensure that each laboratory is NFESC-Evaluated for the analyses they are to perform. Ensure evaluation timeframe does not expire. As of May 22, 2009, Mitkem's NFESC letter expires on March 10, 2010.	Project Chemist: Michael Zamboni/CH2M HILL

1 Ia = compliance with methods, procedures, and contracts [see Table 10, page 117, UFP-QAPP manual, V.1, March 2005.]

IIb = comparison with measurement performance criteria in the SAP [see Table 11, page 118, UFP-QAPP manual, V.1, March 2005]

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SAP Worksheet #36 — Analytical Data Validation (Steps IIa and IIb) Summary Table

Step IIa / IIb	Matrix	Analytical Group[1]	Validation Criteria	Data Validator (title and organizational affiliation)
IIa and IIb	SB	TPH	Analytical methods and laboratory SOPs, as presented in this UFP-SAP, will be used to evaluate compliance against QA/QC criteria. Data may be qualified if a QA/QC exceedance has occurred. Data qualifiers will be those presented in USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA, Rev. Final, October, 1999).	Data Validation Subcontractor: Laura Maschoff/DataQual
	GW			
	SB	SPLPS	Analytical methods and laboratory SOPs, as presented in this UFP-SAP, will be used to evaluate compliance against QA/QC criteria. Data may be qualified if QA/QC exceedances have occurred. Region II Checklists as outlined in SOP No. HW-22 Validating Semivolatile Compounds by SW-846 8270 (EPA Region II, Rev. 3, October, 2006). Additional guidance taken from USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA, Rev. Final, October, 1999).	
		SVOC		
	GW			
	SB	SPLPV	Analytical methods and laboratory SOPs, as presented in this UFP-SAP will be used to evaluate compliance against QA/QC criteria. Data may be qualified if QA/QC exceedances have occurred. Region II Checklists as outlined in SOP No. HW-24 Standard Operating Procedure for the Validation of Organic Data Acquired using SW-846 Method 8260B (EPA Region II, Rev. 2, October, 2006). Additional guidance taken from USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA, Rev. Final, October, 1999).	
		VOC		
	GW			

1 MICRO, FMETAL, and WCHEM data will not be subject to analytical data validation by a third-party data validation subcontractor. CH2M HILL will establish that all required UFP-SAP QC samples were run and met required limits. At a minimum, this will include blanks, laboratory control sample, and calibrations. The laboratory case narrative will be read and any issues will be investigated.

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SAP Worksheet #37 — Usability Assessment

The DQE assesses the effect of the overall analytical process on the "availability" of the analytical data. "Availability" in this context refers to whether results can be used by the project team based on their analytical soundness. If a result is analytically sound, it is available for use for evaluating the performance of the pilot studies and whether meeting the pilot study PRGs is warranted. In order to avoid confusion of terms, the DQE differentiates the "availability" of results from "usability" of results. "Available" results are analytically sound and available for use by the project team to make decisions, even if they are not usable for a particular purpose.

The three major categories of data availability evaluation are laboratory performance, field collection performance (i.e., blank contamination), and matrix interferences. Evaluation of laboratory performance is a check for compliance with the method requirements; in other words, a check of whether the laboratory analyzed the samples within the limits of the analytical method. Additionally, an independent, third-party validator will conduct a review of the laboratory data to assess whether the analytical methods were within required control limits at the time of analysis. Evaluation of potential matrix interferences involves the review of several areas of results, including surrogate spike recoveries, MS recoveries, and duplicate sample results. Evaluation of field collection performance, such as blank contamination and field duplicates, involves the review of field QC and the determination of their effect on the sample results.

The data evaluation and validation is a multi-tiered approach. The process begins with an internal laboratory review, continues with an independent review by a third-party validator, and ends with an overall review by the Navy contractor project chemistry team. While only the data validator is allowed to apply qualifiers to the data, the process provides a medium for essential communication between the laboratory, validator, and project team, and allows for data quality to be thoroughly evaluated.

Data usability evaluation comprises critical assessment of the data with respect to the project objective. Given that the primary objective of the pilot studies is to evaluate the implementability and effectiveness of the proposed in-situ remediation, if so, whether meeting the PRGs warrants no further action, the comprehensive dataset will be reviewed to determine if it is adequate for making the project-specific determinations. Another aspect of the data usability evaluation is whether PALs were met (for non-detect results) and, if not, what the effects are on the project-specific determinations. Not achieving PALs does not necessarily mean project-specific determinations cannot be made; it may lend some uncertainty to those decisions and may mean additional lines of evidence are necessary to make the decisions conclusively, which will be discussed in the data usability evaluation.

Some specific examples of data availability and usability protocol are:

- The third-party data validator is the only party that may apply qualifiers to the data. Minor QC exceedances will result in "estimated" data, represented by J, NJ, and UJ qualifiers. Major QC exceedances will result in "rejected" data, represented by R-qualifiers. The effect on availability and usability of rejected results will be evaluated.

  The use of "estimated" data will be discussed in the report. "Estimated" data are generally considered usable for all purposes. The project team may choose to use "rejected" data in a qualitative manner under some circumstances, if the direction of bias and proximity to a project

SAP Worksheet #37 — Usability Assessment (continued)

action limit are known. For example, if there were a hypothetical location where a benzene detection was rejected because of an extremely low bias, yet the result was still greater than the project action limit, this rejected result would still be usable for demonstrating that an exceedance has occurred.

- While all non-rejected data are available for use to the project team, non-detect (and attributable to blank contamination) results may not be useful if the QL is greater than the associated project action limit. In these cases, the project team will determine whether or not the laboratory would likely have detected the contaminant if present at or above the PAL (i.e., evaluation of the PAL versus the MDL).
- Ten percent of hardcopy analytical data will be checked against the electronic data to identify discrepancies. This check will be performed manually. The check will verify results and data validation qualifiers. This process is intended to identify discrepancies between the hardcopy and electronic data. If any discrepancies are identified during the ten percent verification, the laboratory will be contacted, the discrepancies will be communicated, and the laboratory will resolve the discrepancies.
- If significant deviation is evident between parent samples and their field or laboratory duplicate, the cause will be investigated. The possibility of a switched sample will be examined. Field duplicates are expected to exhibit greater deviation than laboratory duplicates. Field duplicate and laboratory duplicate reproducibility is outlined in Worksheets 12 and 28.
- Significant biases may be evident based on LCS, MS/MSD, and spiked surrogate exceedances. The third-party data validator will consider QC exceedances and biases when applying qualifiers to data. The project team will consider the direction of bias when determining the usability of qualified data compared to PALs. Low biases are expected to occur more frequently than high biases. In the case of rejected non-detect data, low biases represent the inability of the laboratory to detect contaminants that may or may not be present at the site. The project team will act conservatively and understand that it is not known whether or not these compounds are present below, at, or above the PAL. High biases indicate that a result may be lower than it is reported. When high-biased data are greater than a PAL, the project team will examine the proximity of the result to the PAL to determine whether additional data are needed or if the result should simply be considered a PAL exceedance.
- After completion of the data validation, the distribution of applied data validation qualifiers will be examined to determine if there are patterns that negatively affect the usability of data. This information will be compiled into a DQE, which will be presented as an appendix to the project report.
- Deviations from the SAP sampling and analytical protocols will be reviewed to ascertain whether or not they are significant enough to negatively affect the usability of data.

Notes:

1. Completeness is defined as the percentage of analyte results that are judged to be available (i.e. not rejected) compared to the total number of results generated. The objective of the overall completeness goal for this project is set at 95% available data. This goal is inclusive of both field and laboratory analytical data. Results may be considered rejected, based on laboratory QA/QC non-conformances or failures. In rare and extreme circumstances, however, depending on intent of data usage these results may still be useable for project decisions. If rejected data are proposed for use, the rationale supporting their use will be included. If the data are considered not usable, they are not considered in the available data set and therefore do not contribute to the completeness goal. Patterns of rejection are examined by sample and also by analyte as part of the data quality evaluation.
2. Discussions of precision, accuracy, representativeness, completeness, and comparability will be included in the data quality review to describe the impact of data quality on project data quality objectives and data usability.

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Attachment A
Figures

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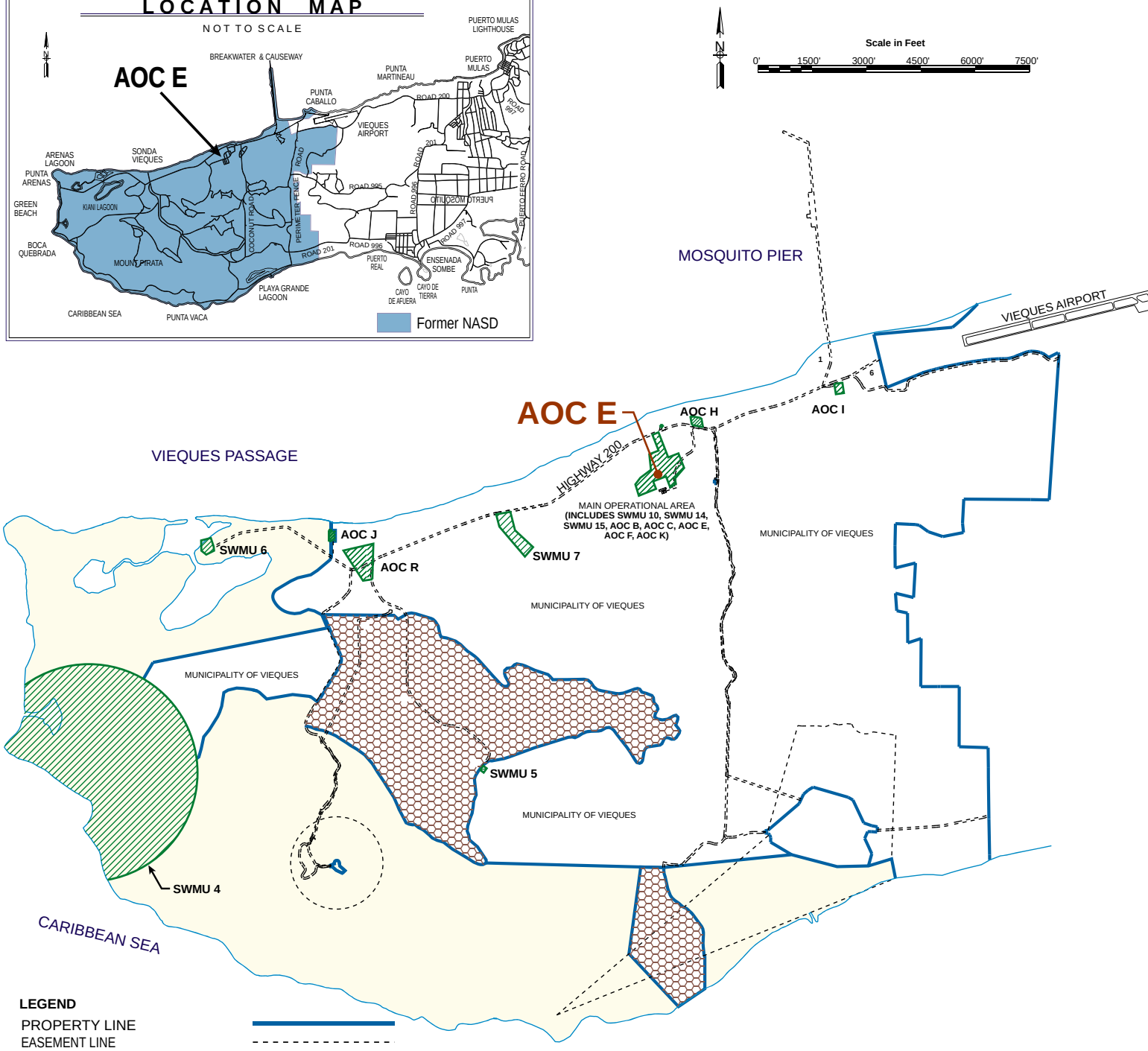


LEGEND

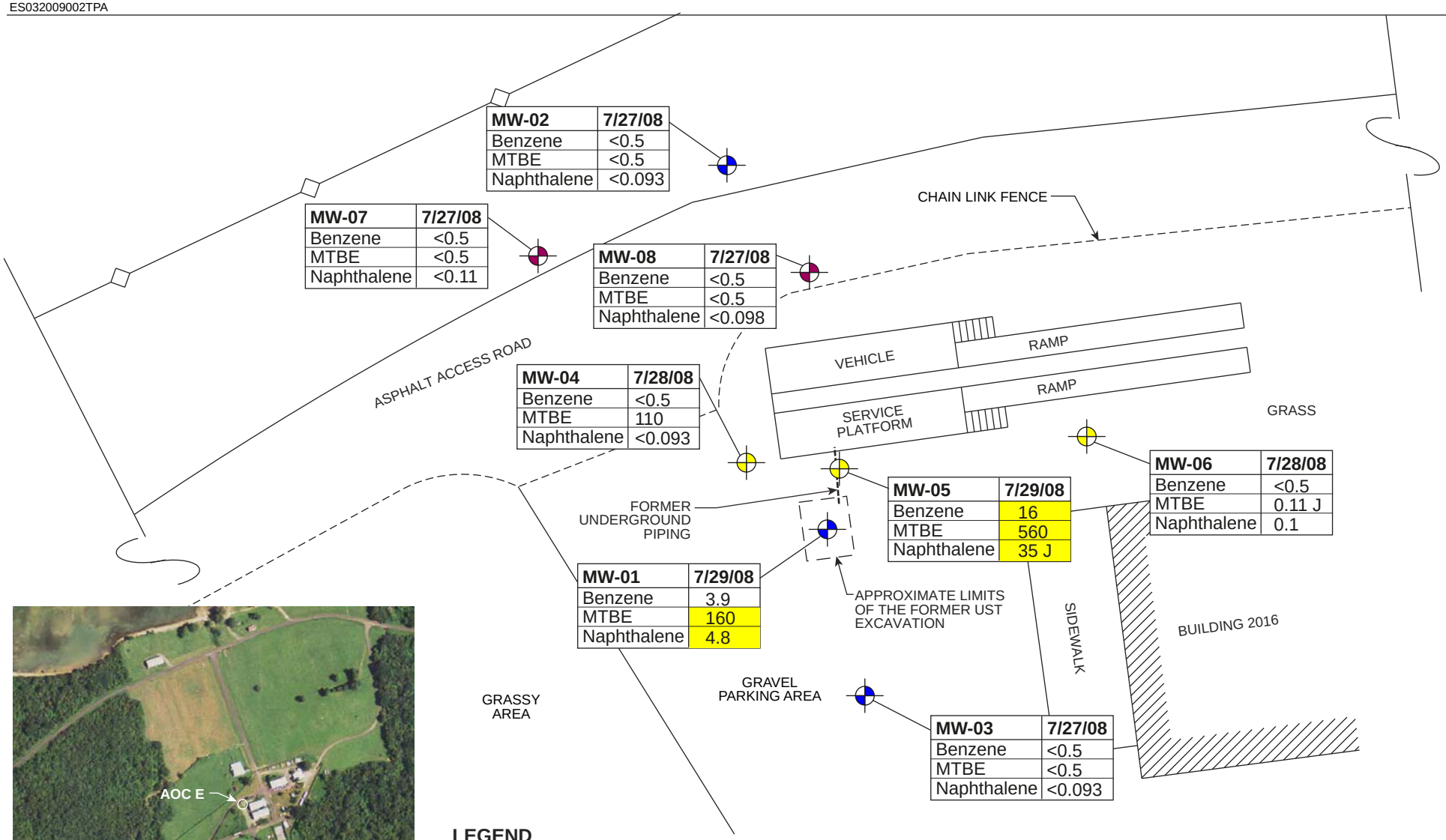
PROPERTY LINE
EASEMENT LINE
APPROXIMATE EDGE OF WATER
UNITED STATES GOVERNMENT\ DEPARTMENT OF THE INTERIOR
PUERTO RICO CONSERVATION TRUST
APPROXIMATE AREAS OF SITES
HIGHWAY OR ROAD

AOC - AREA OF CONCERN
SWMU - SOLID WASTE MANAGEMENT UNIT
NASD - NAVAL AMMUNITION SUPPORT DETACHMENT

SOURCE:
VIEQUES NASD SURVEY LAND TRANSFER & DISPOSAL OVERALL LOCATION SURVEY
PREPARED BY GLENN & SADLER AND LUIS BERRIOS MONTES & ASSOCIATES

FIGURE 1
AOC E Site Location Map
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL



2004 Aerial Photograph

LEGEND

- Monitoring Well Installed during the 1998 Site Characterization
- Monitoring Well Installed during the 2000 PA/SI
- Monitoring Well Installed during the 2002 RI

Notes: The latest COC concentrations (µg/L) sampled in July 2008 are shown; Highlighted values exceeded pilot study PRGs; Concentrations of 1,2-dichloroethane, 2-methylnaphthalene, and total xylenes are below PRGs and not shown.

FIGURE 2
AOC E Monitoring Well Location and COC Concentration Map
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

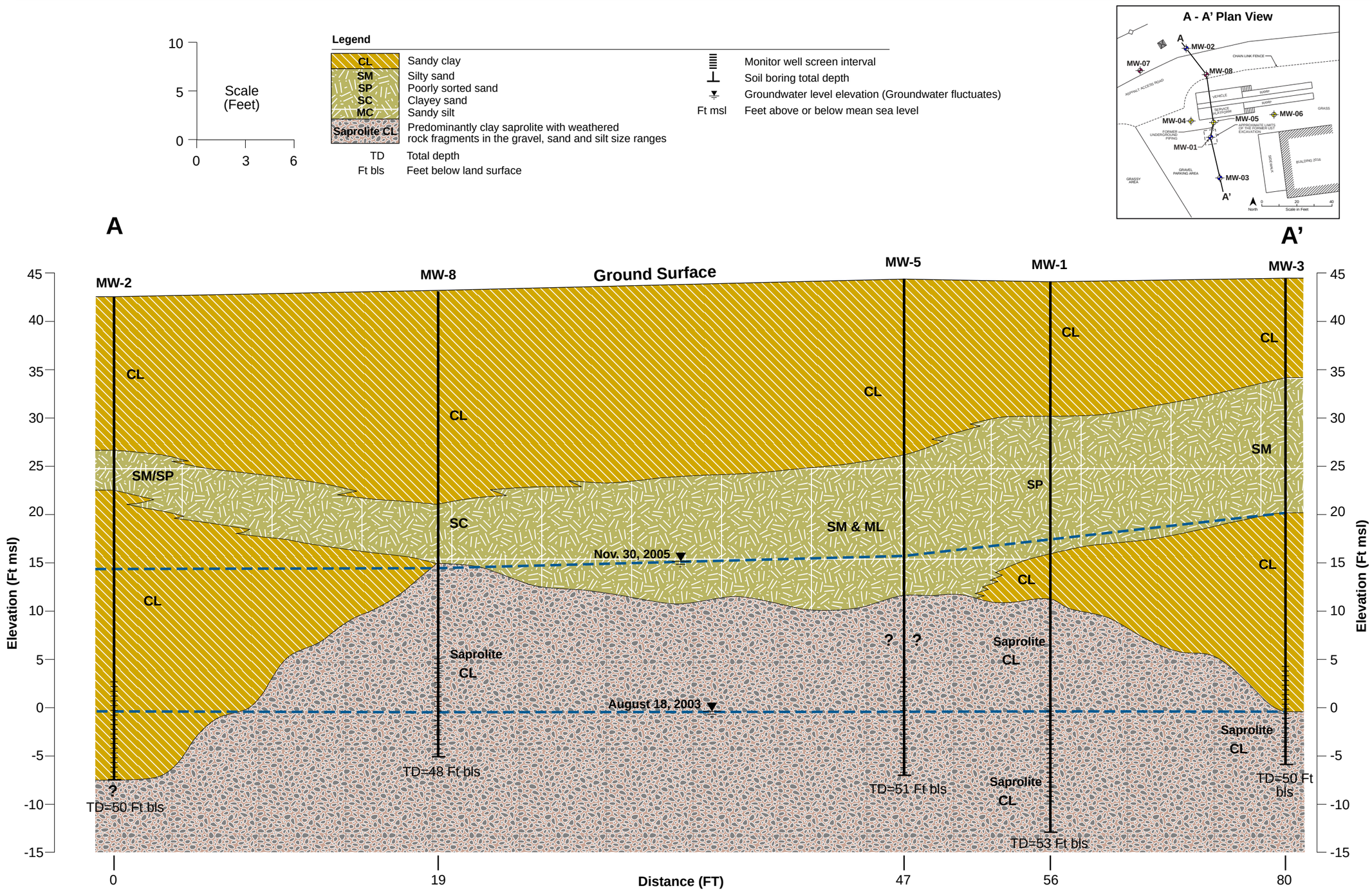
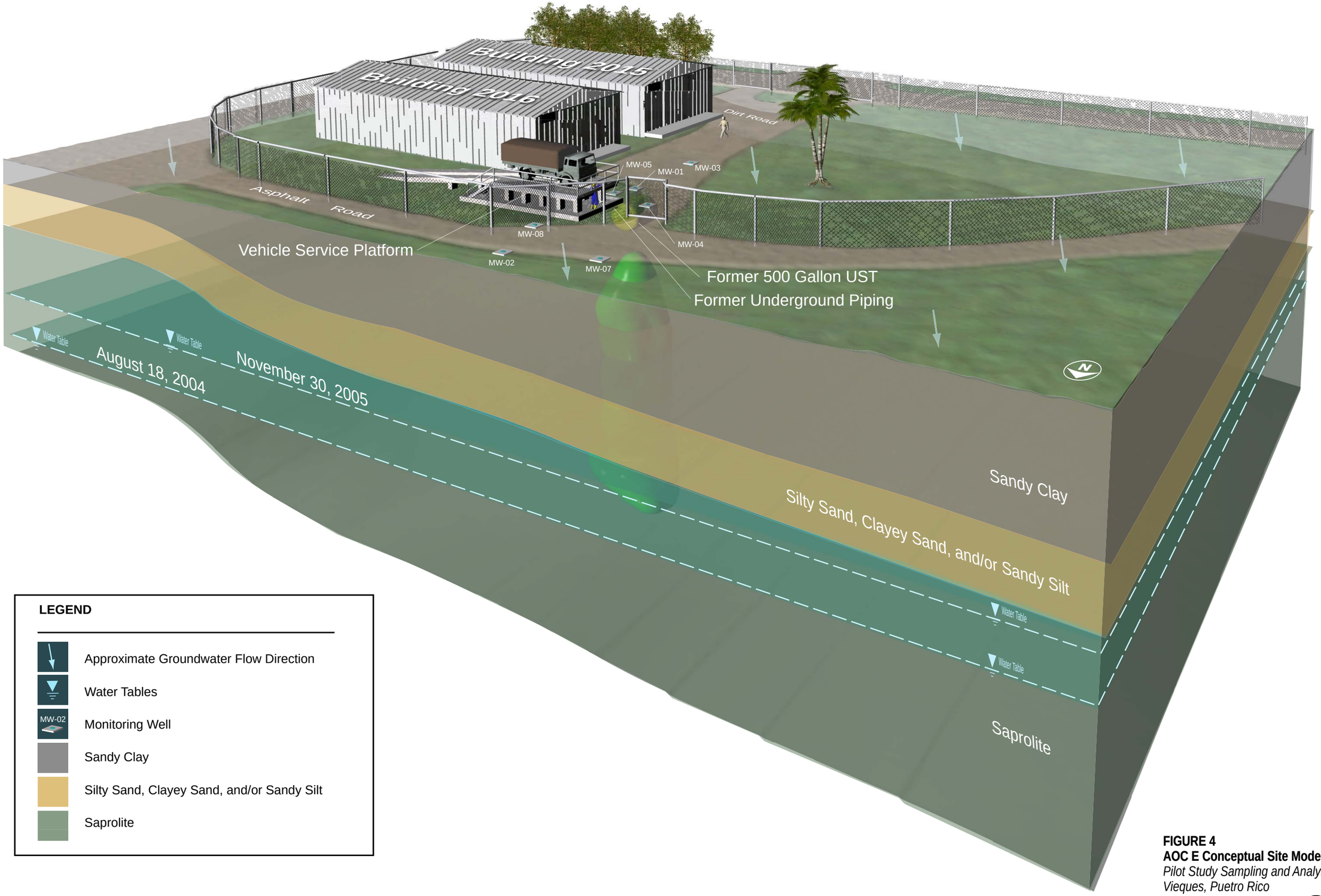


FIGURE 3
AOC E Geologic Cross Section
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

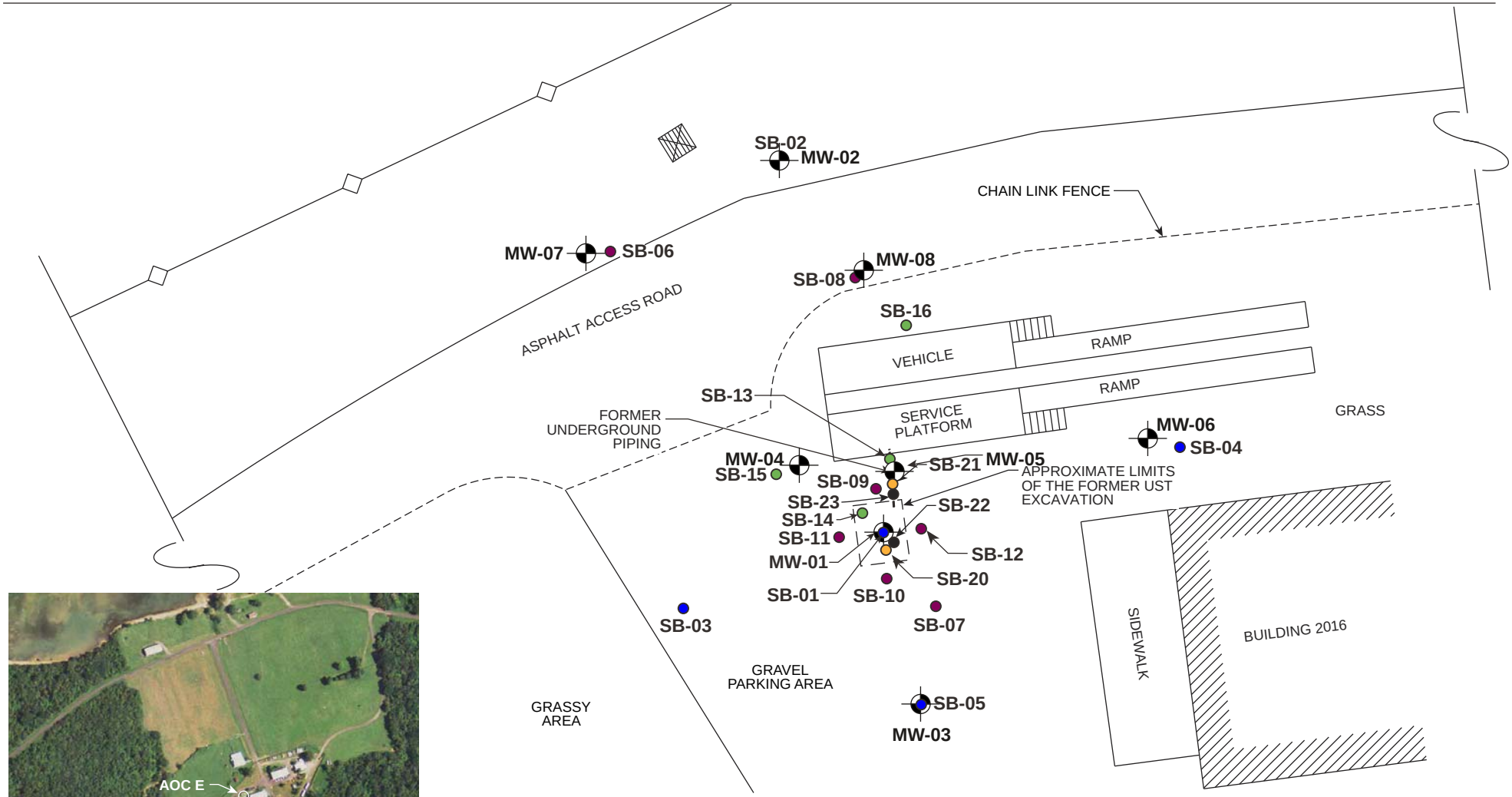


LEGEND

- Approximate Groundwater Flow Direction
- Water Tables
- MW-02 Monitoring Well
- Sandy Clay
- Silty Sand, Clayey Sand, and/or Sandy Silt
- Saprolite

FIGURE 4
AOC E Conceptual Site Model
Pilot Study Sampling and Analysis Plan
Vieques, Puetro Rico

CH2MHILL



2004 Aerial Photograph

LEGEND

- Site Characterization Subsurface Soil Sample Location - 1998
- RI Subsurface Soil Sample Location - 2002
- RI Subsurface Soil Sample Location - 2005
- Post RI Subsurface Soil Sample Location - 2008
- Proposed Confirmatory Soil Sample Locations (Post-Nitrate Injection)
- Monitoring Well

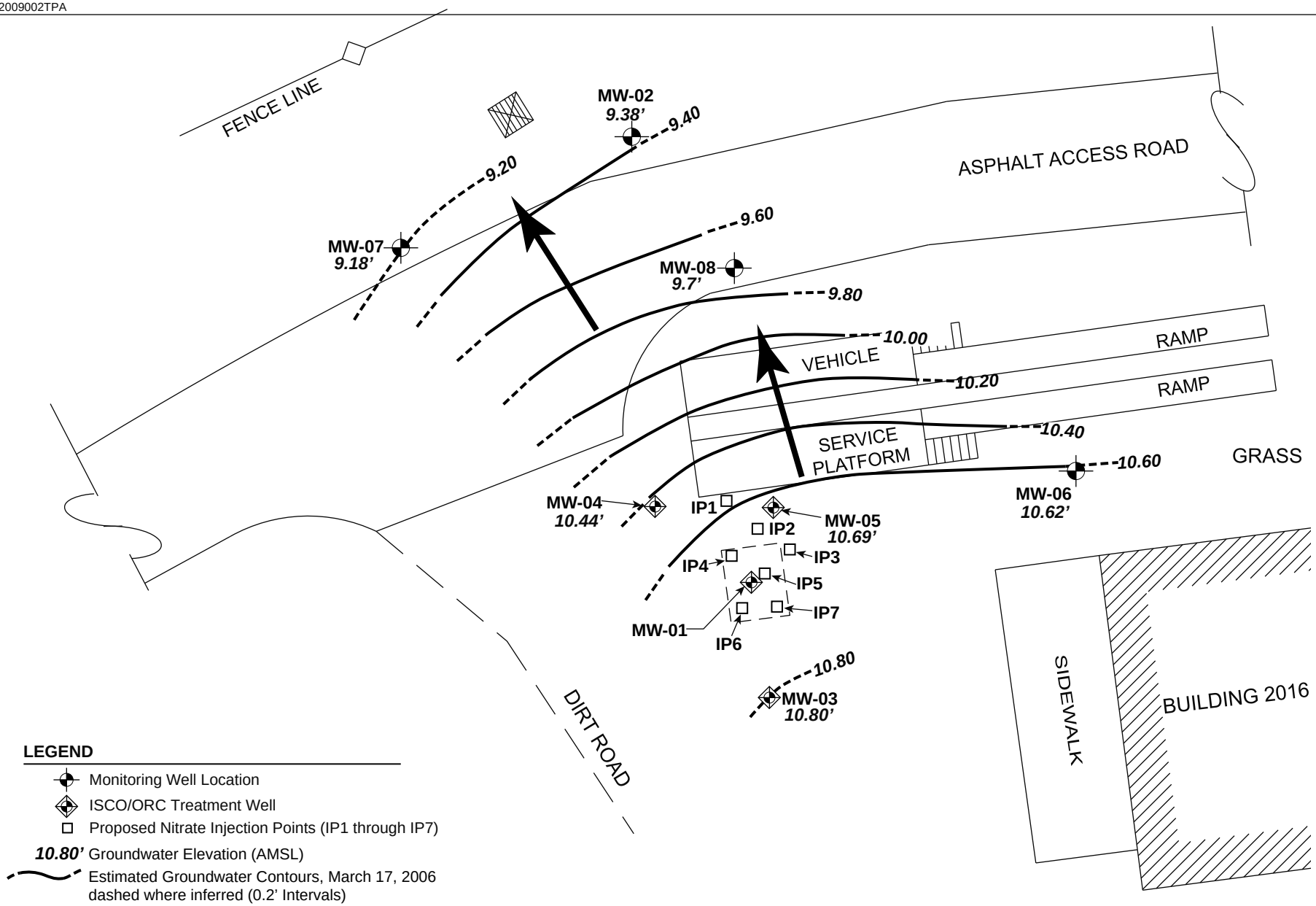
North

0 20 40

Scale in Feet
1" = 20'

FIGURE 5
AOC E Proposed Confirmatory Soil Sample Locations
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL



LEGEND

- Monitoring Well Location
- ISCO/ORC Treatment Well
- Proposed Nitrate Injection Points (IP1 through IP7)
- ***10.80'*** Groundwater Elevation (AMSL)
- Estimated Groundwater Contours, March 17, 2006 dashed where inferred (0.2' Intervals) Groundwater Elevations in FT AMSL
- Estimated Direction of Groundwater Flow

North

0 15 30

Scale in Feet
1″ = 15′

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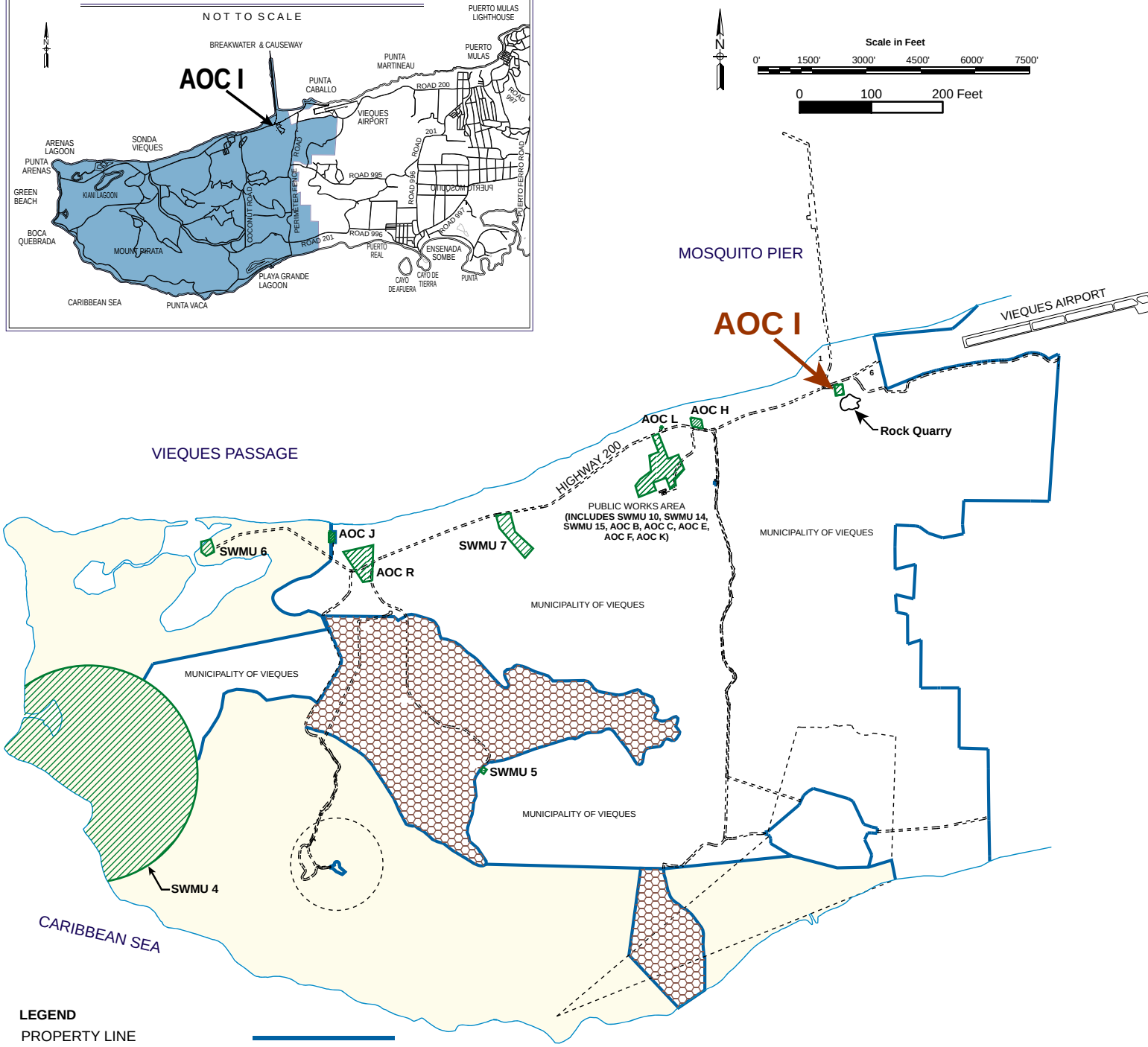
FIGURE 6
AOC E Proposed Nitrate Injection Points and ISCO/ORC Treatment Wells
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico



LEGEND

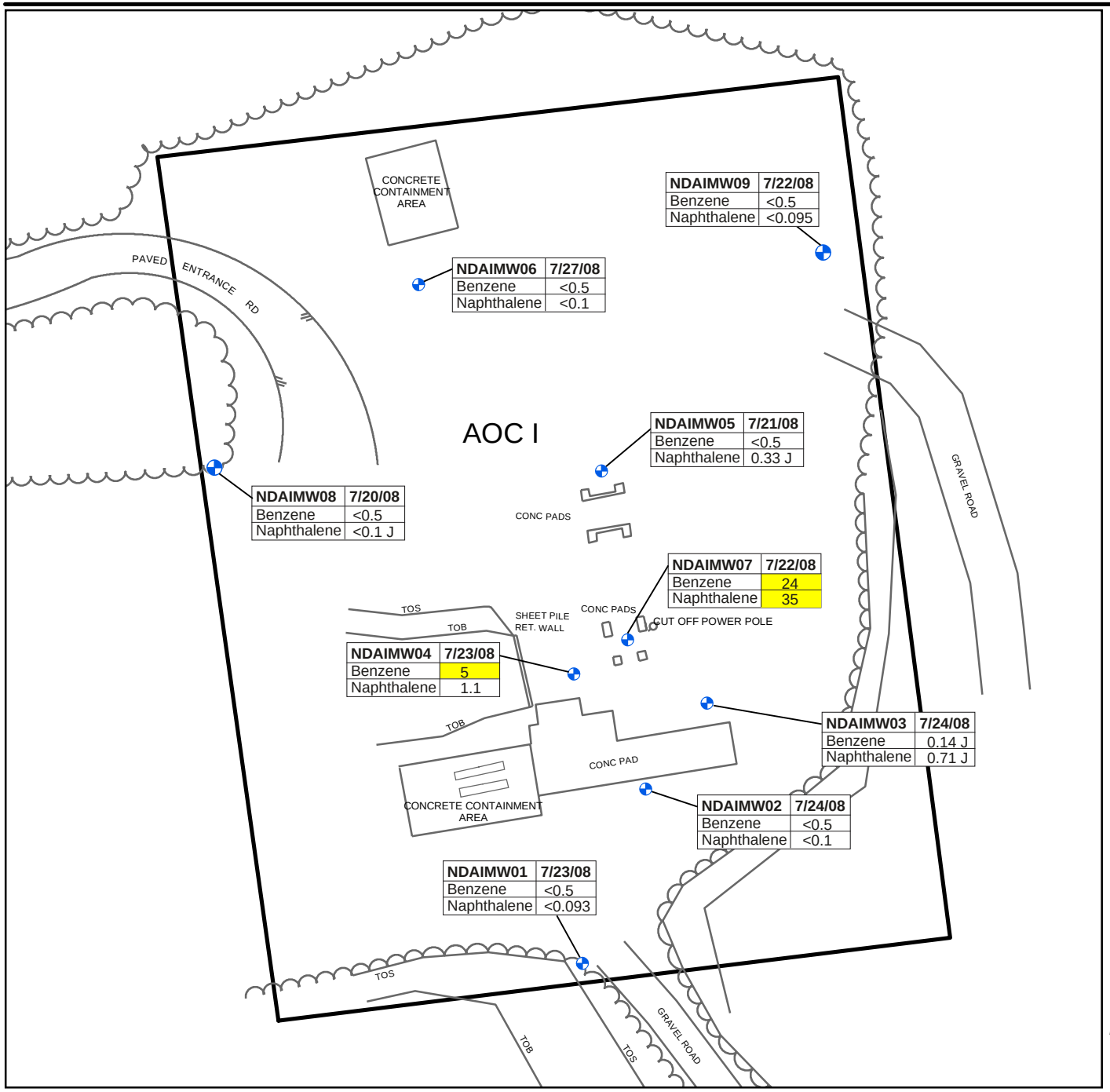
PROPERTY LINE
EASEMENT LINE
APPROXIMATE EDGE OF WATER
UNITED STATES GOVERNMENT\ DEPARTMENT OF THE INTERIOR
PUERTO RICO CONSERVATION TRUST
APPROXIMATE AREAS OF SITES
HIGHWAY OR ROAD

AOC - AREA OF CONCERN
SWMU - SOLID WASTE MANAGEMENT UNIT
NASD - NAVAL AMMUNITION SUPPORT DETACHMENT

SOURCE:
VIEQUES NASD SURVEY LAND TRANSFER & DISPOSAL OVERALL LOCATION SURVEY
PREPARED BY GLENN & SADLER AND LUIS BERRIOS MONTES & ASSOCIATES

FIGURE 7
AOC I Site Location Map
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

PHOTO DATE 1999



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Installed During the RI

N

0 25 50 Feet

Notes: The latest COC concentrations (µg/L) sampled in July 2008 are shown; Highlighted values exceeded pilot study PRGs; Other COC are not shown.

FIGURE 8
AOC I Monitoring Well Location and COC Concentration Map
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

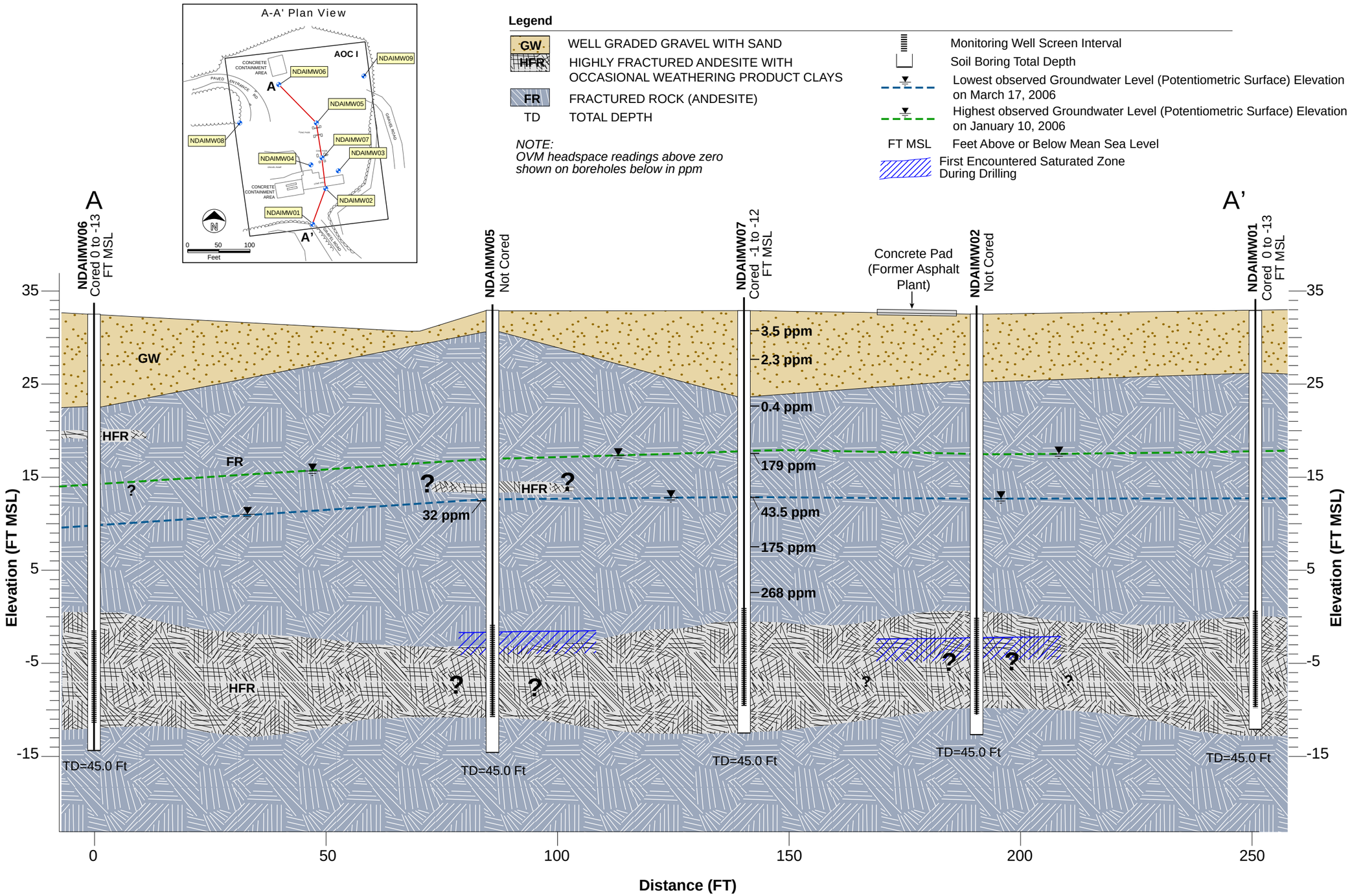


FIGURE 9
AOC I Geologic Cross Section A-A'
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

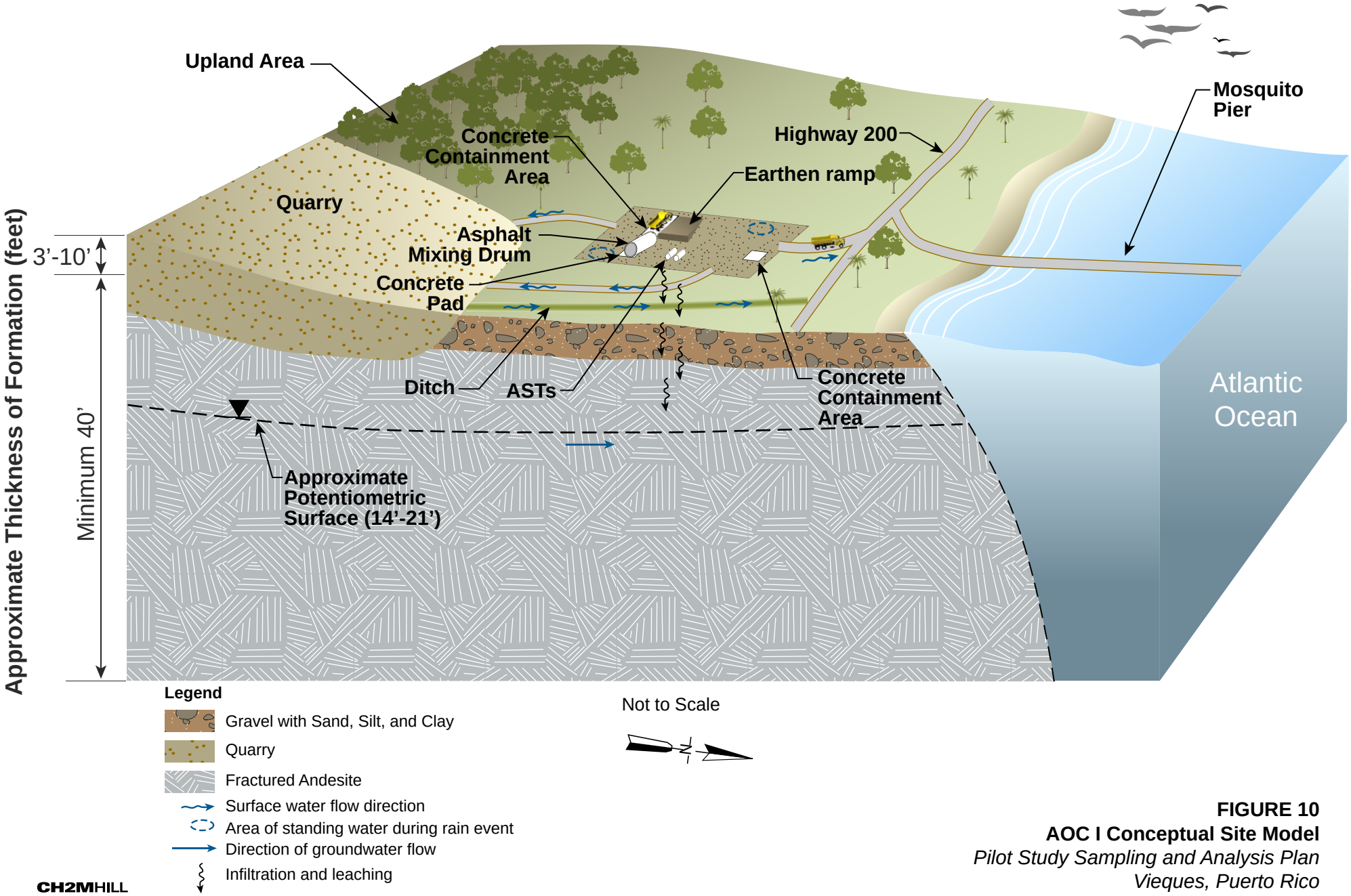
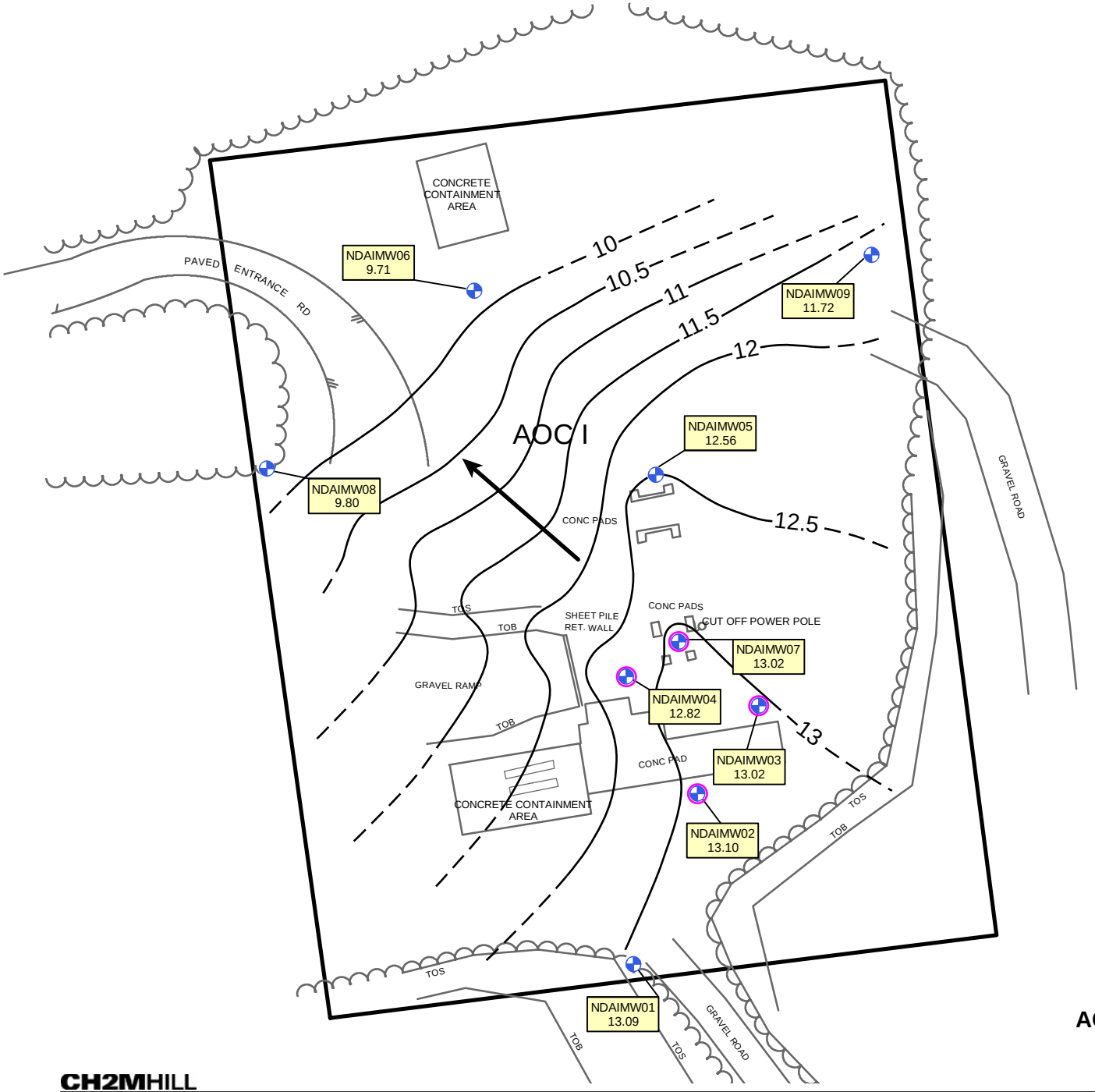


FIGURE 10
AOC I Conceptual Site Model
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL



LEGEND

- AOC I Area
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Location
- ISCO/EISB Treatment Well
- Estimated Groundwater Contours, dashed where inferred (0.5' Intervals)
- Estimated Direction of Groundwater Flow

Groundwater elevations in FT MSL.
Water Level readings taken on March 17, 2006

N

0 25 50 Feet

FIGURE 11
AOC I Proposed ISCO/EISB Treatment Wells
Pilot Study Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL
ES032009002TPA

Attachment B
Proposed Pilot Study of In-Situ Remediation at Vieques, AOC E

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Proposed Pilot Study of In Situ Remediation at Vieques AOC E

PREPARED FOR: Danny Rodriguez/EPA
Wilmarie Rivera/PREQB
Richard Henry/USFWS

PREPARED BY: CH2M HILL, on behalf of the U.S. Navy

COPIES: Kevin Cloe/NAVFAC
Madeline Rivera/NAVFAC
Dan Hood/NAVFAC
Chris Penny/NAVFAC

DATE: December 19, 2008

Introduction

The *Final Remedial Investigation Report, Area of Concern (AOC) E, Former Naval Ammunition Support Detachment (NASD), Vieques, Puerto Rico* (CH2M HILL, 2008) provided detailed site conditions at the former underground storage tank (UST) area and recommended an additional round of soil and groundwater sampling prior to a Feasibly Study (FS) (or pilot study) to evaluate viable remedial alternatives to address the unacceptable risk associated with the contaminated groundwater at AOC E. The additional round of groundwater sampling for the FS was performed in July 2008. The objectives of this Technical Memorandum (TM) are to summarize the pertinent findings of the July 2008 soil and groundwater sampling event, and to present a conceptual pilot study plan to address remediation of the impacted groundwater and unsaturated zone soil at the site.

Since the contaminant concentrations, especially methyl tert-butyl ether (MTBE), have shown a general declining trend over the past few years and the chemicals of concern (COCs) in groundwater are limited to a relatively localized area adjacent to the former UST, evaluation of various remedial alternatives in a traditional FS would not be the most efficient approach for AOC E. Rather, these conditions make the implementation of a pilot study a more appropriate approach for the site in order to determine whether the already low COC concentrations can be reduced to acceptable levels in a shorter timeframe than what could be achieved through natural processes.

The proposed pilot study is a systematic two-step approach for groundwater. The first step involves in-situ chemical oxidation (ISCO) to reduce COC concentrations and condition the aquifer, followed by a second step of enhanced in-situ bioremediation (EISB) to sustain aerobic biodegradation in the aquifer. To support this process and to reduce the potential risk of hydrocarbon leaching to the groundwater, the residual contamination in the unsaturated soil zone will be treated by anoxic, denitrification-based bioremediation (DBB) to increase the intrinsic biodegradation rate and to decrease the residual hydrocarbon mass.

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Site Conditions and Assumptions

The following presents a summary of historical and current site conditions and major assumptions used in the development of the proposed approach.

Geologic and Hydrogeologic Conditions

Based on the soil boring data collected during the historical and current site investigations, the unconsolidated deposits beneath AOC E generally consist of sandy clay of the Qa geologic unit with interspersed silty/clayey sand from ground surface to a depth of approximately 35 feet below ground surface (bgs) in the vicinity of the former UST. The sandy layer is generally above the water table, though its lowest sections are submerged at the site's highest recorded water levels. These deposits overlie a clay-rich saprolite (in-place weathered bedrock material consisting of clay with residual fragments of granodiorite bedrock). The top of the saprolite varies in elevation from approximately 28 feet bgs to below 50 feet bgs.

The saturated unconsolidated material in the proposed pilot AOC E study area is clay-rich and of-low permeability, as evinced by the hydraulic conductivity measured in 2002 (*Final Remedial Investigation Report*, Appendix F; CH2M HILL, 2008) in monitoring well MW-04 of 0.2 feet per day, (7.06×10^{-5} centimeters per second [cm/sec]). A multiphase extraction (MPE) pilot test conducted in 2002 was able to extract the groundwater only at an average flow rate of approximately 0.25 to 0.5 gallon per minute (gpm).

Depth to groundwater typically ranges from approximately 28 to 43 feet bgs, with seasonal fluctuations up to approximately 15 feet. Groundwater has been encountered part of the time in the saprolite, and less often in the lowest portion of the unconsolidated deposits directly above the saprolite. The direction of groundwater flow is north-northwest toward the Vieques Passage. Slug-test data for several onsite monitoring wells suggested a relatively low groundwater velocity (about 1 foot/year). While slug test data in saprolite are prone to a high degree of uncertainty, the general absence of contamination in wells as little as about 50 feet downgradient of the former UST tends to support this velocity estimation.

Summary of Baseline Human Health Risk Assessment (HHRA)

A baseline Human Health Risk Assessment (HHRA) contained in the *Final Remedial Investigation Report* (CH2M HILL, 2008) identified five groundwater COCs comprising 1,2-dichloroethane (1,2-DCA), 2-methylnaphthalene, MTBE, naphthalene, and xylenes, based on groundwater datasets collected during May 2002 and August/September 2004 events. Analysis of additional groundwater samples collected in July 2008 indicated that only benzene, naphthalene, and MTBE exceeded the proposed pilot study preliminary remediation goals (pilot study PRGs, as discussed below). Benzene was detected in only one well (MW-05), at a concentration of 16 micrograms per liter [µg/L], above the Maximum Contaminant Level (MCL) of 5 µg/L; naphthalene was detected at concentrations of 4.8 µg/L in MW-01 and 33 µg/L in well MW-05, above the pilot study PRG of 1.4 µg/L; and MTBE was detected at concentrations of 160 µg/L in well MW-01 and 560 µg/L in well MW-05, above the pilot study PRG of 120 µg/L (summarized in Exhibit 1).

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The HHRA also evaluated the soil data collected during the 2002 RI and the 2005 Supplemental RI (CH2M HILL, 2008). The potential risks based on the direct contact exposure pathways to COCs detected in soil were within the U.S. Environmental Protection Agency (EPA) acceptable range and therefore not a remedial action driver (from a risk standpoint).

Proposed Pilot Study PRGs

PRGs have not been developed for the site-specific groundwater COCs identified in the HHRA. However, for the purposes of considering a potentially suitable remedial technology for the pilot study, the following "Pilot Study PRGs" were considered, based upon the EPA MCLs, or the September 2008 EPA Regional Screening Levels (RSLs) for constituents without MCLs (Exhibit 1).

EXHIBIT 1
Pilot Study PRGs

COCs	July 2008 Maximum Concentrations [a]	Pilot Study PRGs	Source of PRGs
Benzene	**16 µg/L**	5 µg/L	MCL
1,2-dichloroethane	0.5 U µg/L	5 µg/L	MCL
2-methylnaphthalene	21 µg/L	150 µg/L	Hazard Index (HI) of 1 based on the September 2008 EPA Regional Screening Level
MTBE	**560 µg/L**	120 µg/L	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level
Naphthalene	**33 µg/L**	1.4 µg/L	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level
Xylenes, total	30.5 µg/L	10,000 µg/L	MCL

Notes:
[a] Bolded values exceed the PRGs
µg/L – micrograms per liter
U – analyzed for but Non-Detected

Summary of the Most Recent Soil and Groundwater Sampling Results

The additional round of soil and groundwater sampling and analyses in July 2008 produced data that reflect current site conditions and that were used to evaluate the potential for continued natural attenuation of COCs in groundwater. The sampling event consisted of 13 soil samples (2 surface soil and 11 subsurface soil samples) from two soil boring locations (Figure A-1 in Appendix A) and 8 groundwater samples from the existing monitoring wells (Figure A-2 in Appendix A). The soil samples were analyzed for chemical and geotechnical parameters and the groundwater samples were analyzed for chemical and biological parameters. The chemical constituents detected in the soil and groundwater samples are summarized and presented in Tables A-1, A-2, and A-3 of Appendix A. The soil boring logs are included in Appendix B.

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Analysis of soil samples collected in July 2008 indicated that the highest COC concentrations are present at the depth intervals near the soil/groundwater interface and within the smear zone. Data from the Synthetic Precipitation Leaching Procedure (SPLP) analysis of soils from this zone (Table A-2 in Appendix A) indicate that the concentration of volatile organic compounds (VOCs) (chloromethane, ethylbenzene, toluene, and xylene) in the unsaturated soils result in leachate concentrations at least one order of magnitude below the MCL or drinking-water health-advisory standard and are, therefore, not a concern for leaching into the groundwater.

The semivolatile organic compound (SVOC) naphthalene is the only groundwater COC whose concentration in soil may leach from unsaturated soil into groundwater and result in a groundwater concentration exceeding the conservative pilot study PRG of 1.4 µg/L (Exhibit 1). However, it is unlikely the groundwater concentration would exceed EPA's health-advisory life-time value for naphthalene of 100 µg/L (EPA, 2006). The high total organic carbon (TOC) of the unsaturated soils (8,800 to 11,700 mg/kg) combined with naphthalene's intrinsic high coefficient of absorption to organic carbon (Koc) cause this SVOC to absorb to the soil. Binding to soil organic carbon limits leaching and protects groundwater. This interpretation is supported by the naphthalene groundwater concentration of 33 µg/L reported in the July 2008 groundwater data; below EPA's health-advisory life-time value for naphthalene of 100 µg/L (EPA, 2006).

Selected soil samples were also tested for geotechnical properties comprising moisture content, specific gravity, bulk density, hydraulic permeability, Atterberg limits, and grain size. A summary of the geotechnical sampling results are included in Appendix C. In general, the shallow soil (<16 to 18 feet bgs) in the area contains high clay content and has low hydraulic permeability (10^{-7} cm/s). The clay content decreases and the hydraulic permeability increases with depth. The highest hydraulic permeability in the vadose zone soil is approximately 10^{-3} cm/s.

Analysis of groundwater samples collected in July 2008 revealed that three of the six COCs identified during the HHRA were detected at concentrations below the MCLs or pilot study PRGs (see Exhibit 1). Benzene, naphthalene, and MTBE were detected above MCLs or pilot study PRGs (see Exhibit 1). However, concentration trends indicative of natural attenuation are not clear due in part to the historical, intermittent presence of free product.

The concentration of residual, phase separated hydrocarbon (PSH) contamination in groundwater, following the 1996 removal of the leaking UST, exhibits a declining trend (Table 2-2, *Final Remedial Investigation Report*; CH2M HILL, 2008). Free product was historically found in the groundwater directly below the former UST (MW-01), but only a sheen has been observed since the MPE pilot study. Based on the above information, the dissolved phase concentrations of benzene, naphthalene, and MTBE, not PSH, are the primary factors in the selection of an appropriate pilot study technology for groundwater remediation.

Monitored natural attenuation (MNA) parameters along with the concentrations of benzene, naphthalene, MTBE for the two most recent sampling events within the area of groundwater contamination (wells MW-01 and MW-05) are summarized in Exhibit 2. Field parameters and natural attenuation parameters collected since 2004 indicate strong anaerobic conditions within the groundwater contamination area, as evinced by depletion of nitrate, the presence

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of dissolved iron and manganese, and the negative oxidation-reduction potential (ORP). The discovery of a moderate population of facultative anaerobic microbes and significant activity of Benzylsuccinate Synthase, an obligate anaerobic enzyme capable of degrading aromatic COCs, confirms active intrinsic anaerobic biological attenuation processes here. A detailed presentation and interpretation of the biological data is presented in Appendix D.

Even though active anaerobic processes have been confirmed, they exhibit low biodegradation kinetics for the COCs. Much higher biodegradation rates for benzene, naphthalene, and MTBE are possible under aerobic conditions. The proposed pilot study presented below describes a process to evaluate the ability to enhance aerobic conditions and thereby accelerate in-situ bioremediation and reduce the time needed to achieve the pilot study PRGs.

EXHIBIT 2
Summary of Groundwater COC Concentrations, MNA Parameters, and Proposed Goals

Parameter	Well ID	MW01		MW05		Goals
	units	09/01/04	07/29/08	08/30/04	07/28/08	
Dissolved Oxygen	mg/L	0.55	1.70	0.93	2.86	> 2.0
Oxidation Reduction Potential (ORP)	mV	-59.9	-73.0	-14.3	-4.7	>300
pH	std. units	NA	6.48	6.63	6.82	6 - 8
Nitrate-N	mg/L	NA	0.05 U	NA	0.05U	NA
Soluble Iron	mg/L	2.88 J	4.24	0.0732 J	1.36	<0.01
Soluble Manganese	mg/L	1.99	1.71	1.98	1.19	<0.01
Sulfate	mg/L	NA	12.5	NA	12.7	NA
Benzene	µg/L	4.1	3.9	0.81 J	16	<5
MTBE	µg/L	260	160	1,180	560	120
Naphthalene	µg/L	9.5	4.8	5.1 U	33	<1.4
Biomass	cells/mL	NA	28,300	NA	134,000	10^5 -10^8
Total Organic Compounds TOC	mg/L	NA	14.1	NA	7.24	< 5
Alkalinity (as $CaCO_3$)	mg/L	NA	834	NA	81.7	NA

Notes:
$CaCO_3$ – calcium carbonate
cells/mL – cells per milliliter
J –Estimated results
mg/L – milligrams per liter
mV – millivolts
NA – Not Available
µg/L – micrograms per milliliter
U – analyzed for but Not Detected

Pilot Study Approach and Rationale

The proposed pilot-study approach consists of two components: (1) treatment of the unsaturated zone in a single, but pulsed, process; and (2) remediation of the saturated zone in a two-phase process of chemical oxidation, followed by extended biological treatment. The location of injection points, treatment wells, monitoring wells, and groundwater flow is shown in Exhibit 3.

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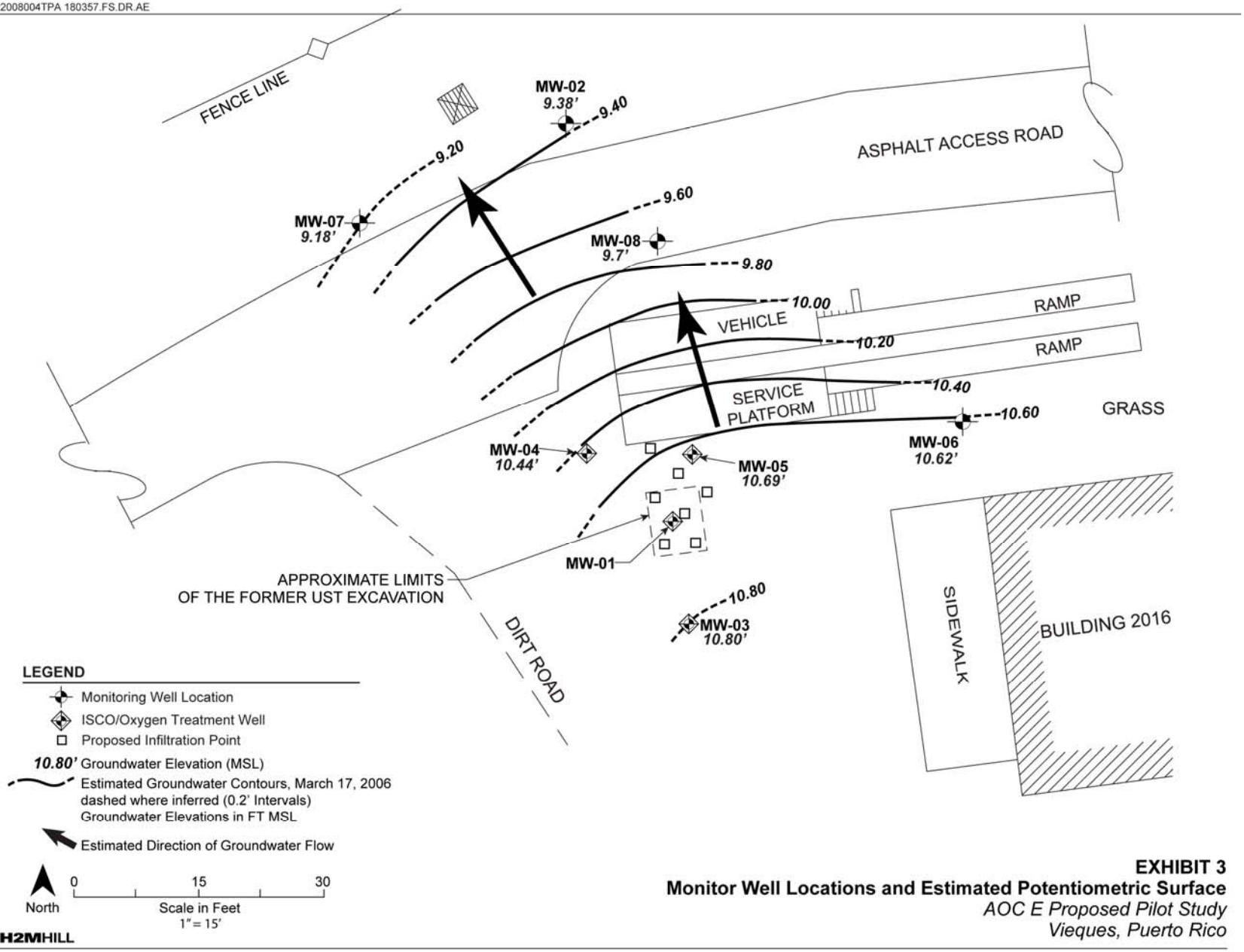

EXHIBIT 3
Monitor Well Locations and Estimated Potentiometric Surface
AOC E Proposed Pilot Study
Vieques, Puerto Rico

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Vadose Zone Soil Denitrification-Based Bioremediation

The goal of the proposed pilot study for unsaturated soils is to reduce the mass of hydrocarbons (primarily naphthalene) in the unsaturated soil through enhanced anoxic biodegradation, thereby reducing the potential for leaching to groundwater. The pilot study will use the denitrification of nitrate to support anoxic biodegradation. Nitrate is highly soluble and mobile in soils and it is a well-documented terminal-electron acceptor that supports anoxic biodegradation of petroleum hydrocarbons and naphthalene. The products of anoxic biodegradation are nitrogen gas, water, and carbon dioxide.

Nitrate solution will be trickle-injected by gravity feed into the unsaturated soils in the area of soil contamination (approximately 10 feet by 15 feet) via seven injection points to a depth of 26 feet bgs. The proposed infiltration locations (Exhibit 3) will be installed using direct-push technology (DPT) near the historical soil boring locations (SB-01, SB-09, SB-12, SB-13, SB-20, and SB-21) (Appendix A, Figure A-1). Temporary borings with continuous-screened polyvinyl chloride (PVC) casing will be connected by a manifold to a tank containing nitrate solution. Pulsed gravity feed, trickle-infiltration will deliver a nitrate solution to the unsaturated zone in three, 3-month intervals followed by a 13-month incubation period. The positive pressure head of active solution infiltration plus natural precipitation will distribute nitrate within the vadose zone during the infiltration period; subsequently, rainfall percolation alone will disperse nitrate during the incubation period. At the end of the incubation period, performance of the DBB treatment will be evaluated by collecting one soil sample from each of two soil borings at locations near historical soil borings SB-20 and SB-21. So that soils data are comparable, the criteria defined in the sampling plan for the July 2008 sampling event will define the selection of the soil-sample depth interval. The samples will be analyzed for TPH, VOCs, SVOCs, and nitrate.

Groundwater ISCO and EISB Pilot Test

The specific objectives of the groundwater remediation portion of the pilot study are:

- To reduce the COC mass
- To adjust the aquifer ORP to the positive, aerobic range (>+300 mV)
- To stimulate aerobic biodegradation of COCs in situ

The proposed pilot study addresses these objectives in a two-stepped systematic approach of ISCO to reduce COC concentrations and adjust the aquifer to aerobic conditions, followed by EISB to sustain aerobic biodegradation of COCs until the oxygen-producing reagents are exhausted.

In Situ Chemical Oxidation (ISCO)

The limited permeability of the saturated zone precludes efficient performance of conventional in-situ bioremediation systems such as pump-and-treat, air sparging/soil-vapor extraction, and oxygen injection. Injecting a slurry-type oxygen-releasing compound directly into the subsurface provides a limited radius of influence (ROI), but associated precipitates may plug the formation. Extended ISCO offers an effective way to reduce COC mass and to adjust the aquifer chemistry to favor biodegradation. The number and close proximity of the existing monitoring wells provide an opportunity to deliver chemical oxidants and microbial enhancements directly to the area of contamination.

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Several chemical oxidants are available for ISCO treatment. Sodium persulfate is recommended as the chemical oxidant because it is strong enough to chemically oxidize, benzene, naphthalene, and MTBE; persistent enough to exploit redistribution by natural diffusion and advective mixing; completely soluble (avoids formation plugging); degrades to naturally occurring salts; and strong enough to condition the aquifer to the positive ORP required for subsequent aerobic biodegradation. Currently, the anaerobic geochemistry provides some soluble iron, but additional ISCO catalysts will be required to activate the persulfate and will be added during the injection process.

Due to the limited formation porosity and slow groundwater velocity, the area of COC groundwater contamination is confined to the vicinity of the former tank hold area and associated piping. To treat this area, activated sodium persulfate solution will be injected under pressure into the saturated zone via four existing monitoring wells (MW-01, MW-03, MW-04, and MW-05) (Exhibit 3). Two ISCO injection events at 3-month intervals are proposed to fulfill the objectives of mass reduction and aquifer adjustment. The first ISCO groundwater injection will be concurrent with mobilization for the vadose zone DPT installation and initial nitrate injection (described in "Vadose Zone Soil Denitrification-Based Bioremediation" above).

Process Evaluation and Treatment Transition Point

Three months after the first ISCO injection, field parameters (temperature, pH, ORP, DO, turbidity, and conductivity) and groundwater samples will be collected from the four monitoring wells (MW-01, MW-03, MW-04 and MW-05). Groundwater samples will be analyzed for selected process performance analytes comprising sulfate, nitrate, soluble iron and soluble manganese, and three COCs: benzene, naphthalene, and MTBE. These COCs were selected as indicators of process performance because reduction in their concentrations is indicative of a broader range of biodegradation and they are the three COCs with concentrations above the pilot study PRGs. The second ISCO injection will be made immediately after sample collection and then, 3 months later, the same suite of field parameters and groundwater samples will be evaluated. In addition to this sampling suite, one additional sample will be collected from well MW-01 to evaluate the microbial community structure by phospholipid fatty acid (PLFA) analysis and quantitative polymerase chain reaction (qPCR) for two biomarker enzymes: naphthalene dioxygenase (NDO) and benzylsuccinate synthase (BSSA).

Groundwater data from the two ISCO treatments will be evaluated to determine if a third ISCO treatment is needed or if the site can transition into the next step, EISB. If the COC concentrations are within 35 percent of the pilot study PRGs, EISB will be implemented. If the COC concentrations are greater than 35 percent of their respective PRGs, a third ISCO injection will be made, incubated for 3 months, and then additional groundwater samples collected, and the data evaluated as described above before transitioning to EISB. Two ISCO treatments are expected to reduce the target COC concentrations and to condition the aquifer for aerobic biodegradation by raising the ORP and by oxidizing soluble metals and residual hydrocarbons. Analysis of groundwater samples after each ISCO treatment will confirm ISCO performance and allow a quantitative projection of the potential impact of a third ISCO treatment over several parameters, including DO, ORP, soluble manganese, soluble iron, benzene, naphthalene and MTBE. The third ISCO treatment is held as a contingency to deliver additional oxidant to the aquifer. COC concentrations greater than

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35 percent of the COC cleanup objectives is the trigger for this contingency but not a performance benchmark for the ISCO treatments. Since the proposed treatment train relies on a two-step process to attain the cleanup objectives and neither is stand alone, if after the third ISCO injection the concentration of target COCs is still greater than 35 percent of the cleanup objectives, the pilot study will proceed as planned with the EISB treatment by installation of the ORC socks and extended incubation. For planning and scheduling purposes, two ISCO treatments are anticipated prior to EISB.

Enhanced In Situ Bioremediation (EISB)

In situ bioremediation will be enhanced by installing filter sleeves (socks) containing an oxygen-releasing reagent into the four wells that were treated with ISCO: MW-01, MW-03, MW-04, and MW-05. The socks release molecular oxygen that supports aerobic biodegradation for up to 9 months. The socks will be deployed approximately 7 months after the last ISCO injection. This allows time to complete the ISCO incubation (3 months), and for sample collection, sample analyses, and data interpretation. The oxygen-delivery socks will be incubated in the wells for 9 months and then removed.

Pilot Study Performance Assessment

Three months after the oxygen-delivery socks are removed, a final set of field parameters and groundwater samples will be collected from the four monitoring wells and analyzed for TPH, VOCs, and SVOCs. An additional sample will be collected from MW-01 to evaluate the microbial community structure by PLFA analysis and qPCR for two biomarker enzymes, NDO and BSSA.

During the same mobilization, performance of the DBB treatment of the unsaturated soils will be evaluated by collecting two soil samples from borings at locations near historical soil borings SB-20 and SB-21 and analyzing them for TPH, VOCs, SVOCs, and nitrate.

Expected Results

Periodic infiltration of the unsaturated soils with nitrate will support DBB of residual hydrocarbons. This anoxic biodegradation process is expected to reduce the hydrocarbon mass in the unsaturated soils and smear zone, thereby reducing the potential for leaching to groundwater.

Activated persulfate will oxidize benzene, naphthalene, and MTBE and other organic compounds on contact and will adjust the aquifer ORP into the positive range to support aerobic biodegradation. The extent of COC destruction and aquifer adjustment will be evaluated by field measurements of dissolved oxygen, ORP, and by sample analysis for selected indicator COCs, soluble iron, and soluble manganese 3 months after each ISCO application. ISCO is expected to set the stage for sustained, aerobic in situ bioremediation by reducing the concentration of COCs and eliminating much of the existing chemical oxygen demand. The oxygen-releasing socks will prolong the aerobic biodegradation environment for an additional 9 months while groundwater flow and water table flux provide natural redistribution of oxygen within the formation. This process is expected to reduce the concentrations of benzene, naphthalene, and MTBE below the pilot study PRGs (Exhibit 1).

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Schedule and Reporting

Exhibit 4 (on page 11) presents the proposed schedule showing unsaturated soils treatment with nitrate, groundwater treatment with ISCO and EISB, and the prescribed monitoring, sample collection, and reporting program. This schedule assumes a start date after agency concurrence on the pilot study approach and assumes the EISB oxygen-delivery sock installations would occur 7 months after the second (or third, if deemed necessary) ISCO injection. The ISCO treatment results, reported as an interim technical memorandum, will provide the decision-point basis for proceeding onward with the EISB process. Approximately 9 months after EISB oxygen-sock installation, the socks will be removed, the monitoring wells will be allowed to equilibrate with the formation for approximately 3 months and a final set of samples will be collected and analyzed as previously described.

Progress and performance will be documented in two reports: a technical memorandum at the transition point between ISCO and EISB, assumed to be at Month 10, and a draft pilot study report, assumed to be at Month 25. Although additional monitoring and reporting during the EISB incubation period were considered, field monitoring and sample collection during the EISB ORC incubation period is not recommended. The high oxygen content in the well's radius of influence during the sock incubation period would not provide a sample representative of the formation. Further, purging the well could interfere with and may compromise the integrity of subsequent data for the pilot study.

The draft pilot study report will be delivered 60 days after the final round of sample data are loaded into the Vieques database. The pilot study report will include recommendations of the path forward (e.g., FS, additional pilot study, no further action, etc.).

References

CH2M HILL. 2008. *Final Remedial Investigation Report, Area of Concern (AOC) E, Former Naval Ammunition Support Detachment Vieques, Puerto Rico*. July.

U.S. Environmental Protection Agency (EPA). 2006. *2006 Edition of the Drinking Water Standards and Health Advisories* EPA 822-R-06-013 Office of Water, U.S. Environmental Protection Agency, Washington, DC. Summer 2006.

Appendices

Appendix A Soil and Groundwater Sampling Data Collected in July 2008

Appendix B Soil Boring Logs - July 2008

Appendix C Soil Geotechnical Sampling Results – July 2008

Appendix D Biological Data AOC E - July 2008

Appendix E Material Safety Data Sheets (MSDS) for ISCO and EISB Reagents

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EXHIBIT 4

Proposed Schedule for AOC E Pilot Study

Tasks	Months																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Unsaturated Soils Treatment with Nitrate/Nutrient Flush																									
Direct Push Installation of Screened Injection Points	X																								
Nitrate Injection Intervals	X			X			X																		
Unsaturated Soil Sampling/Analysis																						X			
ISCO of Saturated Zone and Groundwater																									
ISCO Injection into Existing Wells	X			X																					
Field Monitoring				X			X				X											X			
Groundwater Sample Collection and Analysis				X			X															X			
ISCO Progress Tech Memo and Recommendations										X															
Sustained Aerobic Environment																									
Installation/Incubation of Oxygen Socks into Existing Wells											X														
Remove Oxygen Socks for Well Equilibration																				X					
Draft Pilot Study Report																									X

Notes:
X indicates month of field deployment event or report delivery.
Shading indicates anticipated duration of treatment
Post pilot study soil boring sampling is not included.

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Appendix A
Soil and Groundwater Sampling Data Collected in July 2008

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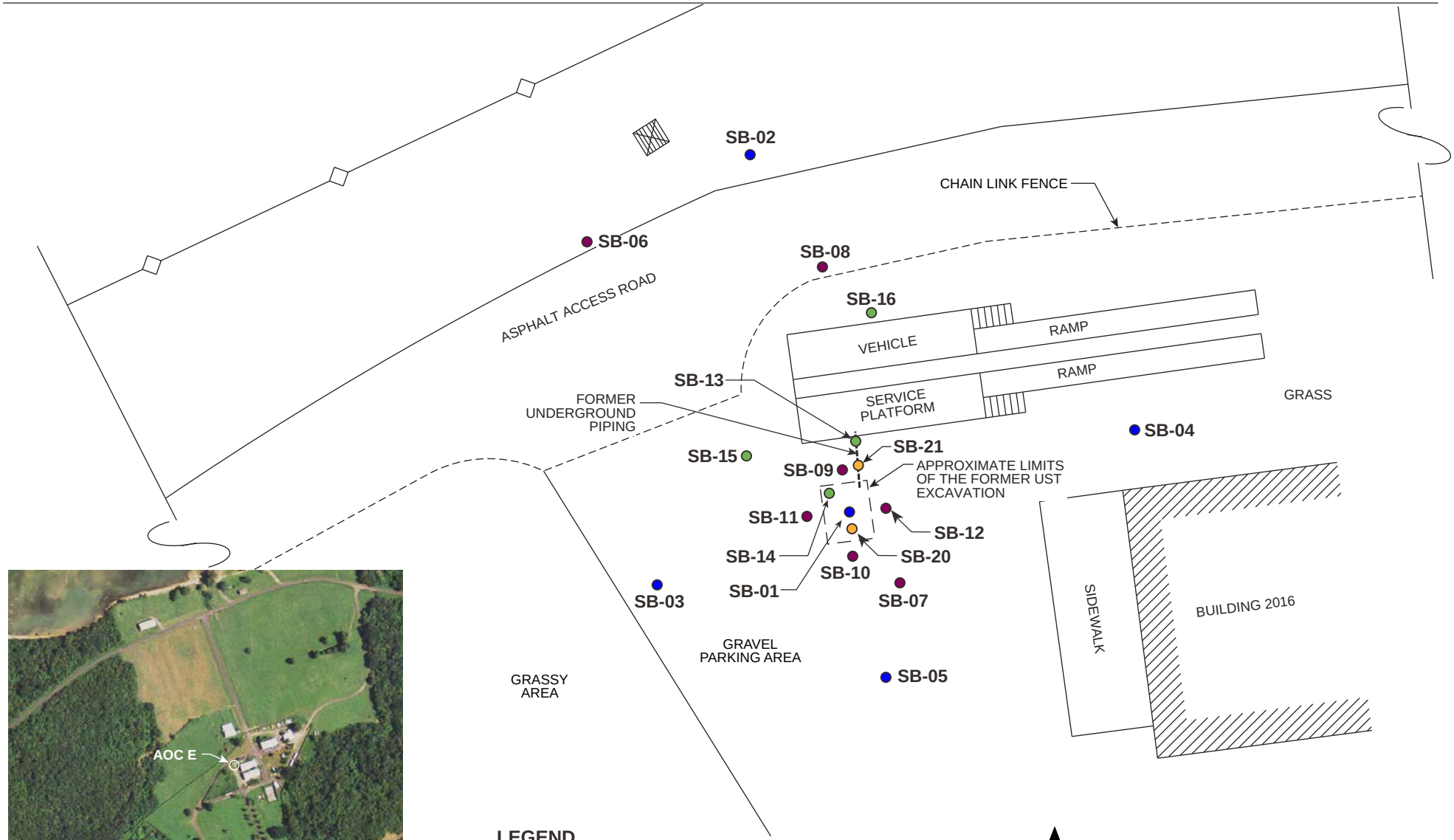

2004 Aerial Photograph

FIGURE A-1
Subsurface Soil Sample Locations
AOC E Technical Memorandum
Vieques, Puerto Rico

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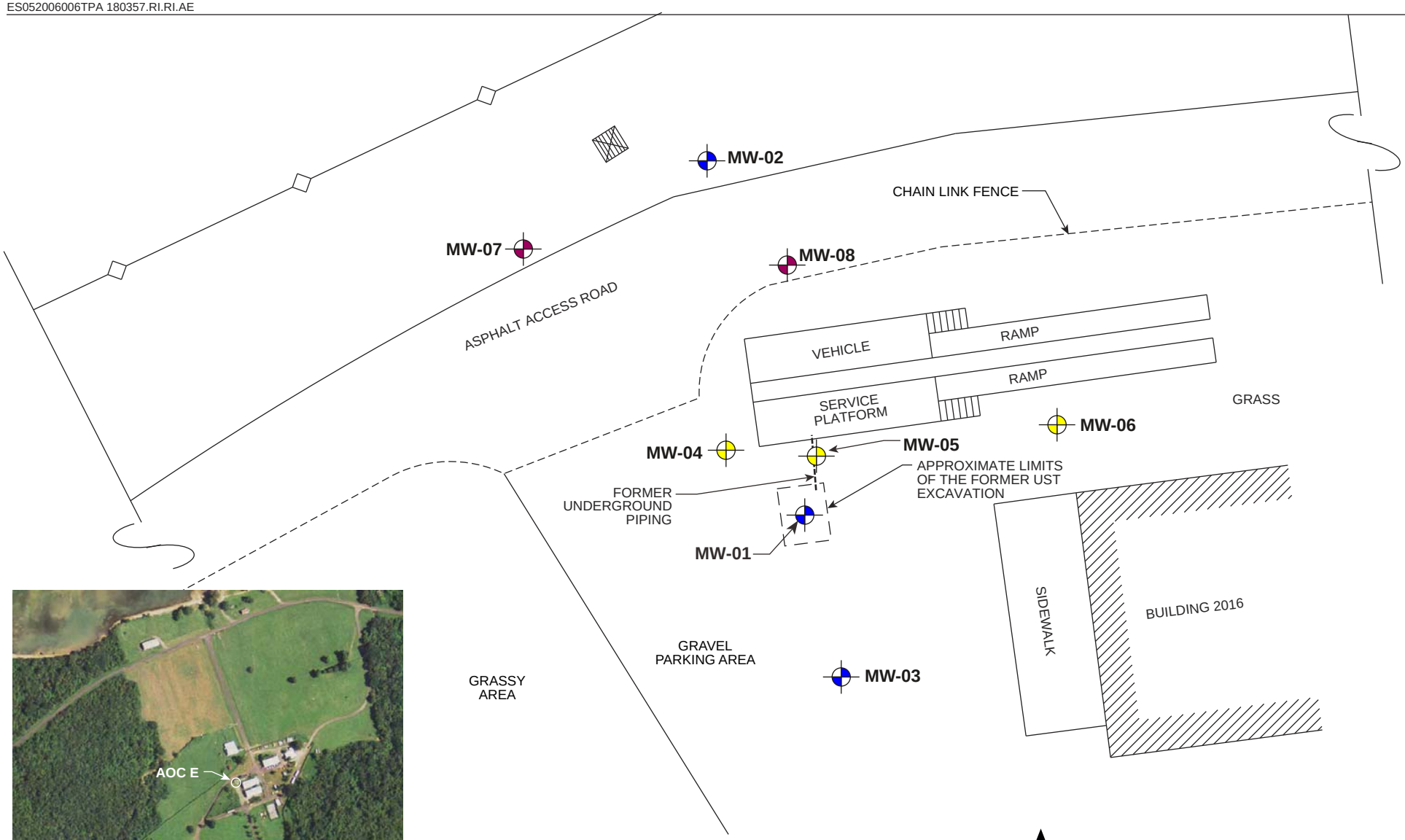

2004 Aerial Photograph

North

0 20 40

Scale in Feet
1" = 20'

LEGEND

- Monitoring Well Installed during the 1998 Site Characterization
- Monitoring Well Installed during the 2000 PA/SI
- Monitoring Well Installed during the 2002 RI

FIGURE A-2
Monitoring Well Locations
AOC E Remedial Investigation Report
Vieques, Puerto Rico

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Table A-1
Vieques - West AOC E
Validated Surface Soil Detected Analytical Results
July 2008

Sample ID	VWAE-SS20-0406-08C	VWAE-SS21-0506-08C
Sample Date	7/17/08	7/16/08
Chemical Name		
Volatile Organic Compounds (UG/KG)		
METHYLCYCLOHEXANE	4.6 U	16
Semivolatile Organic Compounds (UG/KG)		
2-METHYLNAPHTHALENE	8.2 J	6.1 J
ANTHRACENE	1.6 J	7.4 U
BENZO(A)ANTHRACENE	7.6 U	13
BENZO(A)PYRENE	7.6 U	12
BENZO(B)FLUORANTHENE	7.6 U	10
BENZO(G,H,I)PERYLENE	7.6 U	12
BENZO(K)FLUORANTHENE	7.6 U	8.4
CHRYSENE	7.6 U	13
DIBENZO(A,H)ANTHRACENE	7.6 U	8.5
FLUORANTHENE	7.6 U	7.4
FLUORENE	1.7 J	13
INDENO(1,2,3-CD)PYRENE	7.6 U	11
NAPHTHALENE	7 J	6.2 J
PHENANTHRENE	2.8 J	7.8
PYRENE	2.1 J	22 J
Total Metals (MG/KG)		
ALUMINUM	16,000	20,500
ARSENIC	0.71 J	0.82 J
BARIUM	115	139
BERYLLIUM	0.21 J	0.34 J
CALCIUM	3,210	3,600
CHROMIUM	16.8	13.2
COBALT	10.6	13.7
COPPER	34.1	40.2
IRON	23,700	28,600
MAGNESIUM	3,390	4,570
MANGANESE	687	1,100
NICKEL	7.4	8.4
POTASSIUM	1,830 J	1,890 J
SILVER	1.1 U	0.19 J
VANADIUM	62.9	71.7
ZINC	43.9	48.6
Total Petroleum Hydrocarbons (MG/KG)		
TPH-diesel range	11 U	8.8 J
TPH-oil range	32	200

Notes:

J - Analyte present. Value may or may not be accurate or precise

NA - Not analyzed

R - Unreliable Result

U - The material was analyed for, but not detected

UJ - Analyte not detected, quantitation limit may be inaccurate

MG/KG - Milligrams per kilogram

UG/KG - Micrograms per kilogram

Shading indicates detection

Table A-2
Vieques - West AOC E
Validated Subsurface Soil Detected Analytical Results
July 2008

Sample ID	VWAE-SB20-0810-08C	VWAE-SB20-1618-08C	VWAE-SB20-2022-08C	VWAE-SB20-2830-08C	VWAE-SB20-3234-08C	VWAE-SB20P-1618-08C	VWAE-SB21-0910-08C	VWAE-SB21-1618-08C	VWAE-SB21-1820-08C	VWAE-SB21-2930-08C	VWAE-SB21-3436-08C	VWAE-SB21-3638-08C	VWAE-SB21P-0910-08C
Sample Date	7/18/08	7/18/08	7/18/08	7/18/08	7/18/08	7/18/08	7/16/08	7/16/08	7/16/08	7/16/08	7/17/08	7/17/08	7/16/08
Chemical Name													
Volatile Organic Compounds (UG/KG)													
1,2-DICHLOROBENZENE	4.6 U	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	90 J	270 U	260 U	240 J	900 U	940 U	240 U
2-BUTANONE	9.1 U	8.6 U	8.7 U	8.9 U	7.8 U	8.8 U	490 U	110 J	130 J	520 U	1800 U	1900 U	480 U
BENZENE	4.6 UJ	4.3 UJ	4.3 U	4.5 U	3.9 U	4.4 U	240 U	270 U	260 U	390	380 J	940 U	240 U
CHLOROMETHANE	0.47 J	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	240 U	270 U	260 U	260 U	900 U	940 U	240 U
ETHYLBENZENE	4.6 UJ	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	2,300	1,100	1,400	9,000	7,100	5,200	2,200
ISOPROPYLBENZENE	4.6 UJ	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	970	620	840	3,000	1,700	1,300	830
M,P-XYLENE	NA	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	150 J	850	1,300	50,000	29,000	27,000	150 J
METHYL TERT-BUTYL ETHER	4.6 UJ	4.3 U	4.3 U	1.3 J	0.3 J	4.4 U	240 U	270 U	260 U	260 U	900 U	940 U	240 U
METHYLCYCLOHEXANE	4.6 UJ	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	480	270 U	260 U	720	820 J	640 J	580
O-XYLENE	4.6 UJ	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	240 U	240 J	490	22,000	570 J	3,800	240 U
TOLUENE	4.6 UJ	4.3 U	4.3 U	4.5 U	3.9 U	4.4 U	240 U	270 U	260 U	6,300	900 U	940 U	240 U
SPLP Volatile Organic Compounds (UG/L)													
1,2-DICHLOROBENZENE	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	3 J	3 J	NA	NA
CARBON DISULFIDE	10 U	NA	NA	2 J	NA	NA	NA	NA	NA	2 J	3 J	NA	NA
CHLOROMETHANE	7 J	NA	NA	2 J	NA	NA	NA	NA	NA	15	11	NA	NA
ETHYLBENZENE	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	27	19	NA	NA
ISOPROPYLBENZENE	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	5 J	5 J	NA	NA
METHYL ACETATE	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	2 J	2 J	NA	NA
TOLUENE	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	26	10 U	NA	NA
XYLENE (TOTAL)	10 U	NA	NA	10 U	NA	NA	NA	NA	NA	180	100	NA	NA
Semivolatile Organic Compounds (UG/KG)													
1,1'-BIPHENYL	190 U	180 U	180 U	190 U	NA	180 U	220	200 U	1400 U	340	190	110 J	380
2-METHYLNAPHTHALENE	3.8 U	19 J	8 J	7.4 U	NA	8.7 J	2,900	10,000	14,000	6,600	3,200	2,300	4,300
ACENAPHTHENE	3.8 UJ	7.1 U	180 U	7.4 U	NA	180 U	23	270	320 J	160 J	100 J	94 J	150 J
ACENAPHTHYLENE	3.8 U	7.1 U	180 U	7.4 U	NA	180 U	22 U	38 U	38 U	7.5 U	22 U	21	22 U
ACETOPHENONE	90 J	180 U	180 U	190 U	NA	180 U	190 U	200 U	1400 U	190 U	180 U	180 U	190 U
ANTHRACENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	36	110	85	360	61	77	49
BENZO(A)ANTHRACENE	3.8 U	1.3 J	7.2 U	7.4 U	NA	7.1 U	83	310	260	280	130	100	140
BENZO(A)PYRENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	26	82	92	43 J	36	37	45
BENZO(B)FLUORANTHENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	31	86	91	82 J	43	27	52
BENZO(G,H,I)PERYLENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	40	140	160	72 J	63	54	70
BENZO(K)FLUORANTHENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	18 J	56	72	7.5 U	27	27	30
BIS(2-ETHYLHEXYL)PHTHALATE	190 U	180 U	180 U	190 U	NA	180 U	530 J	1,600	1,700	1,200	720	670	5,500 J
BUTYL BENZYL PHTHALATE	190 U	180 U	180 U	190 U	NA	180 U	190	590	900 J	420	170 J	180	440
CHRYSENE	3.8 U	1.2 J	1.1 J	7.4 U	NA	7.1 U	59	210	240	140 J	100	85	110
DIBENZO(A,H)ANTHRACENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	9.6 J	17 J	15 J	7.5 U	7.8 J	11 J	16 J
DI-N-BUTYL PHTHALATE	190 U	180 U	180 U	190 U	NA	180 U	190 U	61 J	1400 U	190 U	180 U	180 U	190 U
FLUORANTHENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	50	200	290 J	50	100	88	85
FLUORENE	3.8 U	3.4 J	1.7 J	7.4 U	NA	1.7 J	140	460	650 J	320	210	180	220
INDENO(1,2,3-CD)PYRENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	18 J	48	54	7.5 U	24	22	29
NAPHTHALENE	3.8 U	14 J	7 J	7.4 U	NA	7.1 J	1,500	5,500	7,600	3,900	2,100	1,800	2,600
PHENANTHRENE	3.8 U	7.1 U	7.2 U	7.4 U	NA	7.1 U	220	900	1,400	410	540	480	600
PHENOLS	39 J	180 U	180 U	190 U	NA	180 U	190 U	200 U	1400 U	190 U	180 U	180 U	190 U
PYRENE	3.8 U	2.6 J	2.2 J	7.4 U	NA	1.9 J	150	810	500 J	380	330	310	360
SPLP Semivolatile Organic Compounds (UG/L)													
2-METHYLNAPHTHALENE	50 U	NA	NA	50 U	NA	NA	NA	NA	NA	52	52	NA	NA
BIS(2-ETHYLHEXYL)PHTHALATE	50 U	NA	NA	21 J	NA	NA	NA	NA	NA	38 J	21 J	NA	NA
NAPHTHALENE	50 U	NA	NA	50 U	NA	NA	NA	NA	NA	71	80	NA	NA
Total Metals (MG/KG)													
ALUMINUM	19,700	7,290	9,080	30,200	NA	8,500	11,900	8,700	5,460	13,100	11,000	6,690	9,230
ARSENIC	0.84 J	0.31 J	1.1 U	2.2	NA	0.38 J	0.51 J	0.42 J	1.1 U	0.57 J	0.54 J	0.51 J	1.2 U
BARIUM	224 J	65.3	76.6	356 J	NA	78.1	97.4	79.6	49.3	126 J	111 J	66.4	118
BERYLLIUM	0.57 U	0.1 J	0.14 J	0.56 U	NA	0.12 J	0.17 J	0.13 J	0.086 J	0.55 U	0.53 U	0.13 J	0.19 J
CALCIUM	4,240	2,010	2,200	10,500	NA	2,300	2,590	2,110	1,720	2,290	5,740	5,840	2,340
CHROMIUM	16.1	6.7	7.9	39.3	NA	9.8	9.8	8.8	4.6	10.1	21.7	59.3	10.9
COBALT	18.8 J	5.1 J	6	29.5 J	NA	6	7.3	6.1	3.6 J	15 J	7.3 J	1.1 J	9.5
COPPER	44.5	19.3	22.1	68.2	NA	23.2	33.8	23.3	13.1	25.5	17.3	9.1	34.8
IRON	27,700	14,100	15,600	53,400	NA	16,100	18,900	16,400	10,600	22,800	14,800	12,000	16,500
LEAD	3.8	1.3 R	1.4 R	1.7	NA	1.9 R	12.6 R	6.3 R	5.3 R	7.7	3.6	3.2 R	19.1 R
MAGNESIUM	5,050	2,030	2,350	19,900	NA	2,460	3,170	2,390	1,540	2,080	3,970	2,180	3,250
MANGANESE	1,120 J	367	451	1,250 J	NA	423	551	496	278	480 J	309 J	264	771
MERCURY	0.11 U	0.1 U	0.11 U	0.11 U	NA	0.1 U	0.12 U	0.1 U	0.11 U	0.11 U	0.11 U	0.51	0.11 U
NICKEL	9.2	4.2 U	4.3 U	23.5	NA	4.3 U	5.3	4.2 U	4.4 U	3.6 J	6.3	5 U	5.3
POTASSIUM	2,430 J	976 J	1,080 J	256 J	NA	1,090 J	1,160 J	1,210 J	660 J	596 J	491 J	1,220 J	1,210 J
VANADIUM	71.7	43.5	45.7	176	NA	48.5	61.6	49.9	31.8	76.5	37	10.9	50.8
ZINC	49.2	20.2	28.2	69.1	NA	23.9	86.2	24.7	17.4	26.6	25.9	14.5	109
SPLP Metals (UG/L)													
ALUMINUM	34,900	NA	NA	31,400	NA	NA	NA	NA	NA	29,000	2,980	NA	NA
ANTIMONY	4.2 J	NA	NA	4 J	NA	NA	NA	NA	NA	3.5 UJ	3.5 UJ	NA	NA
BARIUM	173	NA	NA	209	NA	NA	NA	NA	NA	165	35.2	NA	NA
BERYLLIUM	0.58	NA	NA	0.29	NA	NA	NA	NA	NA	0.77	0.18 U	NA	NA
CALCIUM	5,780	NA	NA	6,740	NA	NA	NA	NA	NA	8,210	3,690	NA	NA
CHROMIUM	28.6	NA	NA	44.4	NA	NA	NA	NA	NA	23.1	3.6	NA	NA
COBALT	8.7	NA	NA	18.3	NA	NA	NA	NA	NA	16.1	4.1 U	NA	NA
COPPER	74.7	NA	NA	83.3	NA	NA	NA	NA	NA	46.5	7.3	NA	NA

Table A-2
Vieques - West AOC E
Validated Subsurface Soil Detected Analytical Results
July 2008

Sample ID	VWAE-SB20-0810-08C	VWAE-SB20-1618-08C	VWAE-SB20-2022-08C	VWAE-SB20-2830-08C	VWAE-SB20-3234-08C	VWAE-SB20P-1618-08C	VWAE-SB21-0910-08C	VWAE-SB21-1618-08C	VWAE-SB21-1820-08C	VWAE-SB21-2930-08C	VWAE-SB21-3436-08C	VWAE-SB21-3638-08C	VWAE-SB21P-0910-08C
Sample Date	7/18/08	7/18/08	7/18/08	7/18/08	7/18/08	7/18/08	7/16/08	7/16/08	7/16/08	7/16/08	7/17/08	7/17/08	7/16/08
Chemical Name													
IRON	53,200	NA	NA	61,400	NA	NA	NA	NA	NA	47,500	3,930	NA	NA
LEAD	3.1	NA	NA	2.2	NA	NA	NA	NA	NA	17.5	1.5 U	NA	NA
MAGNESIUM	9,450	NA	NA	11,000	NA	NA	NA	NA	NA	5,920	2,250	NA	NA
MANGANESE	421	NA	NA	950	NA	NA	NA	NA	NA	379	83.1	NA	NA
NICKEL	13.2	NA	NA	20.6	NA	NA	NA	NA	NA	9.6	2	NA	NA
POTASSIUM	4,070 J	NA	NA	581 J	NA	NA	NA	NA	NA	1,260 J	253 J	NA	NA
SODIUM	14,400	NA	NA	13,000	NA	NA	NA	NA	NA	23,900	12,000	NA	NA
VANADIUM	130	NA	NA	216	NA	NA	NA	NA	NA	168	39.4	NA	NA
ZINC	96.8 J	NA	NA	54.9 J	NA	NA	NA	NA	NA	87.1 J	11.8 J	NA	NA
Wet Chemistry (PH)													
PH	7.97	NA	NA	6.64	NA	NA	NA	NA	NA	7.88	8.26	NA	NA
TOC	903	NA	NA	4,420	NA	NA	NA	NA	NA	11,700	8,870	NA	NA
Total Petroleum Hydrocarbons (MG/KG)													
TPH-diesel range	11 U	11 U	11 U	11 U	NA	11 U	670	830	1,600	600	380	370	430
TPH-gas range	0.45 U	0.45 U	0.42 U	0.45 U	0.38 U	0.44 U	1.7	2.7	1.2	5	18	14	1.8
TPH-oil range	13 J	31	21	18	NA	23	2,700	5,100	5,700	3,200	1,900	2,200	2,000
SPLP Total Petroleum Hydrocarbons (MG/L)													
TPH-diesel range	2.5 UJ	NA	NA	2.5 U	NA	NA	NA	NA	NA	0.97 J	0.79 J	NA	NA
TPH-gas range	0.5 U	NA	NA	0.5 U	NA	NA	NA	NA	NA	1.2	1.1	NA	NA

Notes:

J - Analyte present. Value may or may not be accurate or precise
NA - Not analyzed
R - Unreliable Result
U - The material was analyed for, but not detected
UJ - Analyte not detected, quantitation limit may be inaccurate
MG/KG - Milligrams per kilogram
MG/L - Milligrams per liter
PCT - Percent
PH - pH units
RATIO - ratio
UG/KG - Micrograms per kilogram
UG/L - Micrograms per liter
Shading indicates detection

CTO-010
Vieques - West AOC E
Validated Groundwater Detected Analytical Results
July 2008

Sample ID	VWAE-MW01-08C		VWAE-MW01P-08C		VWAE-MW02-08C	VWAE-MW03-08C	VWAE-MW04-08C		VWAE-MW05-08C		VWAE-MW06-08C	VWAE-MW07-08C	VWAE-MW08-08C
Sample Date	7/29/08		7/29/08		7/27/08	7/27/08	7/28/08		7/29/08		7/28/08	7/27/08	7/27/08
Chemical Name													
Volatile Organic Compounds (UG/L)													
1,1,2-TRICHLOROETHANE	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.19 J	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U
1,2-DICHLOROBENZENE	4.1	NA	4.3	NA	0.5 U	0.5 U	2.9	NA	6.1	NA	0.5 U	0.5 U	0.5 U
BENZENE	3.9	NA	3.8	NA	0.5 U	0.5 U	0.5 U	NA	16	NA	0.5 U	0.5 U	0.5 U
BROMOFORM	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	0.5 U	NA	0.15 J	0.5 U	0.5 U
CARBON DISULFIDE	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	1.1	NA	0.5 U	0.5 U	0.5 U
CHLOROBENZENE	0.15 J	NA	0.15 J	NA	0.5 U	0.5 U	0.48 J	NA	0.21 J	NA	0.5 U	0.5 U	0.5 U
CHLOROFORM	0.5 U	NA	0.5 U	NA	0.2 J	0.43 J	0.5 U	NA	0.5 U	NA	0.5 U	0.1 J	0.23 J
CHLOROMETHANE	0.5 U	NA	0.14 J	NA	0.5 U	0.5 U	0.5 U	NA	0.1 J	NA	0.5 U	0.5 U	0.1 J
CYCLOHEXANE	3.3	NA	3.4	NA	0.5 U	0.5 U	0.36 J	NA	3.8	NA	0.5 U	0.5 U	0.5 U
DIBROMOCHLOROMETHANE	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	0.5 U	NA	0.16 J	0.5 U	0.5 U
ETHYLBENZENE	11	NA	10	NA	0.5 U	0.5 U	0.5 U	NA	54	NA	0.5 U	0.5 U	0.5 U
ISOPROPYLBENZENE	6.5	NA	6.5	NA	0.5 U	0.5 U	0.5 U	NA	14	NA	0.5 U	0.5 U	0.5 U
m- and p-Xylene	0.86	NA	0.8	NA	0.5 U	0.5 U	0.5 U	NA	28	NA	0.5 U	0.5 U	0.5 U
METHYL TERT-BUTYL ETHER	160	NA	150	NA	0.5 U	0.5 U	110	NA	560	NA	0.11 J	0.5 U	0.5 U
METHYLCYCLOHEXANE	3.3	NA	3.1	NA	0.5 U	0.5 U	0.24 J	NA	4.7	NA	0.5 U	0.5 U	0.5 U
O-XYLENE	0.19 J	NA	0.22 J	NA	0.5 U	0.5 U	0.5 U	NA	2.5	NA	0.5 U	0.5 U	0.5 U
TRICHLOROFLUOROMETHANE	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	0.5 U	NA	0.5 U	0.5 U	0.13 J
Semivolatile Organic Compounds (UG/L)													
2-METHYLNAPHTHALENE	6.3	NA	4.3	NA	0.093 U	0.095 U	0.05 J	NA	16 J	NA	0.035 J	0.11 U	0.098 U
ACENAPHTHENE	0.21	NA	0.22	NA	0.093 U	0.095 U	0.064 J	NA	0.48 J	NA	0.093 U	0.11 U	0.098 U
ACENAPHTHYLENE	0.18	NA	0.17	NA	0.093 U	0.095 U	0.033 J	NA	0.27 J	NA	0.093 U	0.11 U	0.098 U
ANTHRACENE	0.21	NA	0.21	NA	0.12	0.095 U	0.093 U	NA	0.11 J	NA	0.093 U	0.11 U	0.098 U
BENZO(A)ANTHRACENE	0.093 U	NA	0.098 U	NA	0.11	0.095 U	0.093 U	NA	0.058 J	NA	0.093 U	0.11 U	0.098 U
BENZO(A)PYRENE	0.093 U	NA	0.098 U	NA	0.17	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
BENZO(B)FLUORANTHENE	0.093 U	NA	0.098 U	NA	0.086 J	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
BENZO(G,H,I)PERYLENE	0.093 U	NA	0.098 U	NA	0.092 J	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
BENZO(K)FLUORANTHENE	0.093 U	NA	0.098 U	NA	0.097	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
BIS(2-ETHYLHEXYL)PHTHALATE	4.7 U	NA	4.9 U	NA	4.7 U	3.5 J	4.7 U	NA	5.6 U	NA	4.7 U	5.3 U	4.9 U
CHRYSENE	0.093 U	NA	0.098 U	NA	0.12	0.095 U	0.093 U	NA	0.056 J	NA	0.093 U	0.11 U	0.098 U
DIBENZO(A,H)ANTHRACENE	0.093 U	NA	0.098 U	NA	0.094	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
FLUORANTHENE	0.14	NA	0.14	NA	0.11	0.095 U	0.028 J	NA	0.068 J	NA	0.093 U	0.11 U	0.098 U
FLUORENE	0.67	NA	0.68	NA	0.093 U	0.095 U	0.093 U	NA	1.4	NA	0.093 U	0.11 U	0.098 U
INDENO(1,2,3-CD)PYRENE	0.093 U	NA	0.098 U	NA	0.11	0.095 U	0.093 U	NA	0.11 UJ	NA	0.093 U	0.11 U	0.098 U
NAPHTHALENE	4.8	NA	4.3	NA	0.093 U	0.095 U	0.093 U	NA	35 J	NA	0.1	0.11 U	0.098 U
PENTACHLOROPHENOL	0.19 UJ	NA	0.2 UJ	NA	9.3 U	0.12 J	0.19 UJ	NA	0.63 J	NA	0.19 UJ	11 U	9.8 U
PHENANTHRENE	0.6	NA	0.61	NA	0.077 J	0.095 U	0.077 J	NA	0.45 J	NA	0.093 U	0.11 U	0.098 U
PYRENE	0.29	NA	0.32	NA	0.15	0.095 U	0.093 U	NA	0.38 J	NA	0.093 U	0.11 U	0.098 U
Total Metals (UG/L)													
ALUMINUM	200 U	NA	200 U	NA	200 U	200 U	8,530 J	NA	221 J	NA	200 U	347	200 U
ANTIMONY	0.04 J	NA	0.038 J	NA	0.11 J	0.02 J	0.074 J	NA	0.054 J	NA	2 UJ	2 U	0.037 J
ARSENIC	2.3 J	NA	2.1 J	NA	0.33 J	0.54 J	1.5 J	NA	5.6 J	NA	0.36 J	0.58 J	0.52 J
BARIUM	267 J	NA	234 J	NA	132	157	585 J	NA	278 J	NA	240 J	103	129
BERYLLIUM	1 U	NA	1 U	NA	1 U	1 U	0.19 J	NA	1 U	NA	1 U	1 U	1 U
CADMIUM	1 U	NA	1 U	NA	1 U	1 U	0.3 J	NA	0.032 J	NA	1 U	1 U	1 U
CALCIUM	96,500	NA	98,500	NA	54,700	60,700	105,000	NA	72,700	NA	73,600	46,600	52,800
CHROMIUM	2 U	NA	2 U	NA	4.8	1 J	9.3	NA	2 U	NA	2 U	0.6 J	0.52 J
COBALT	0.54 J	NA	0.48 J	NA	0.27 J	0.24 J	6.8 J	NA	0.55 J	NA	0.38 J	0.63 J	0.26 J
COPPER	2.7 J	NA	2.9 J	NA	2.4	2.5	44.8 J	NA	3.7 J	NA	2.2 J	2 J	2 J
IRON	5,300	NA	5,510	NA	100 U	100 U	15,300	NA	2,870	NA	100 U	413	100 U
LEAD	0.2 J	NA	0.19 J	NA	1 U	0.092 J	6.7 J	NA	0.7 J	NA	0.1 J	0.13 J	0.056 J
MAGNESIUM	57,300	NA	58,300	NA	32,200	39,100	58,300	NA	43,300	NA	50,600	31,900	34,500
MANGANESE	1,850 J	NA	1,650 J	NA	12.7	39.9 J	4,510 J	NA	1,690 J	NA	49.1 J	22.8	8.7
NICKEL	3.1 J	NA	2.9 J	NA	16.1	2.2	6.8 J	NA	2.8 J	NA	3.6 J	2.1	1.9
SELENIUM	2.1 J	NA	1.8 J	NA	2.7 J	2.9 J	1.8 J	NA	2.3 J	NA	3.1 J	2.1 J	2.7 J
SODIUM	167,000	NA	171,000	NA	131,000	133,000	146,000	NA	149,000	NA	120,000	112,000	121,000
THALLIUM	1 U	NA	1 U	NA	1 U	1 U	0.039 J	NA	1 U	NA	1 U	1 U	1 U
VANADIUM	5 U	NA	5 U	NA	13.5	13	54.3 J	NA	5 U	NA	19.1 J	21	13.5
ZINC	3 J	NA	4.3 J	NA	2.6	2.4 J	74.9 J	NA	6.8 J	NA	3.3 J	2.4	2.6
Dissolved Metals (UG/L)													
ALUMINUM	200 U	NA	200 U	NA	200 U	200 U	200 U	NA	200 U	NA	200 U	220	200 U
ANTIMONY	0.034 J	NA	0.039 J	NA	2 U	2 U	0.043 J	NA	0.039 J	NA	2 U	2 U	2 U
ARSENIC	1.5	NA	1.7	NA	1 U	1 U	1.7	NA	3.1	NA	0.33 J	1 U	1 U
BARIUM	231 J	NA	256 J	NA	130	162	436 J	NA	237 J	NA	216 J	128 R	10 U
CADMIUM	1 U	NA	1 U	NA	1 U	1 U	0.03 J	NA	1 U	NA	1 U	1 U	1 U
CALCIUM	96,000	NA	97,000	NA	55,800	65,900	96,600	NA	70,900	NA	76,200	47,300	53,600
CHROMIUM	2 U	NA	2 U	NA	2 U	2 U	2 U	NA	2 U	NA	0.92 J	2 U	2 U

CTO-010
Vieques - West AOC E
Validated Groundwater Detected Analytical Results
July 2008

Sample ID	VWAE-MW01-08C		VWAE-MW01P-08C		VWAE-MW02-08C	VWAE-MW03-08C	VWAE-MW04-08C		VWAE-MW05-08C		VWAE-MW06-08C	VWAE-MW07-08C	VWAE-MW08-08C
Sample Date	7/29/08		7/29/08		7/27/08	7/27/08	7/28/08		7/29/08		7/28/08	7/27/08	7/27/08
Chemical Name													
COPPER	1.9 J	NA	2.1 J	NA	1.6 R	2.4	2.1 J	NA	1.8 J	NA	2.3 J	1.8 R	2 U
IRON	4,210	NA	4,240	NA	100 U	100 U	4,080	NA	1,360	NA	100 U	206	100 U
LEAD	1 U	NA	1 U	NA	1 U	1 U	0.062 J	NA	0.12 J	NA	1 U	1 U	1 U
MAGNESIUM	57,800	NA	58,500	NA	32,900	42,400	55,100	NA	43,900	NA	52,500	32,400	35,200
MANGANESE	1,630	NA	1,710	NA	4.2 R	54.8 R	4,040	NA	1,190	NA	20.9	1 R	1 R
NICKEL	2.1 J	NA	2.3 J	NA	12	2.5	5.2 J	NA	1.9 J	NA	2.7 J	1.7 R	1 U
SELENIUM	1.8 J	NA	2.1 J	NA	5 U	5 U	2.1 J	NA	2.2 J	NA	3.2 J	5 U	5 U
SODIUM	163,000	NA	162,000	NA	134,000	144,000	139,000	NA	149,000	NA	117,000	115,000	123,000
VANADIUM	0.75 J	NA	0.86 J	NA	12.9 R	14.1 R	0.65 J	NA	0.49 J	NA	17	13.4 R	5 U
ZINC	1.9 J	NA	2.4 J	NA	2.4 R	3.5 J	4.5 J	NA	3.2 J	NA	2 J	2 R	2 U
Wet Chemistry (MG/L)													
CHLORIDE	26.6	NA	29.5	NA	NA	NA	36.3	NA	2 U	NA	NA	NA	NA
ETHANE	0.1 J	8 U	0.2 J	15 U	NA	NA	2 U	3 U	2 U	8 U	NA	NA	NA
FERROUS IRON	0.49	NA	0.57	NA	NA	NA	1.08	NA	0.32 B	NA	NA	NA	NA
SULFATE	12.5	NA	13.3	NA	NA	NA	13.2	NA	12.7	NA	NA	NA	NA
TOC	14.1	NA	13.2	NA	NA	NA	18.9	NA	7.24	NA	NA	NA	NA
TOTAL ALKALINITY	834	NA	817	NA	NA	NA	789	NA	81.7	NA	NA	NA	NA
Total Petroleum Hydrocarbons (MG/L)													
TPH-diesel range	0.29 J	NA	0.34 J	NA	0.5 U	0.5 U	0.15 J	NA	0.56	NA	0.5 U	0.53 U	0.5 U
TPH-gas range	1.4	NA	1.5	NA	0.5 U	0.5 U	0.55	NA	4.8	NA	0.5 U	0.5 U	0.5 U
TPH-oil range	1 U	NA	1 U	NA	1 U	1 U	1 U	NA	2.1	NA	1 U	1.1 U	1 U
General Microbial Analyses (GC/ML)													
MTBE Degrading Bacteria PM1	1.72	NA	NA	NA	NA	NA	NA	NA	8.8	NA	NA	NA	NA
Biomass (CELLS/ML)													
Cells	28,300	NA	NA	NA	NA	NA	NA	NA	134,000	NA	NA	NA	NA
Community Structure (PCT)													
Actinomycetes	13.0	NA	NA	NA	NA	NA	NA	NA	6.53	NA	NA	NA	NA
Anaerobic metal reducers	2.16	NA	NA	NA	NA	NA	NA	NA	2.23	NA	NA	NA	NA
Eukaryotes	1.46	NA	NA	NA	NA	NA	NA	NA	1.94	NA	NA	NA	NA
Firmicutes	11.0	NA	NA	NA	NA	NA	NA	NA	13.6	NA	NA	NA	NA
General Nsats	24.0	NA	NA	NA	NA	NA	NA	NA	22.6	NA	NA	NA	NA
Proteobacteria	48.4	NA	NA	NA	NA	NA	NA	NA	53.1	NA	NA	NA	NA
Dechlorinating Bacteria (GC/ML)													
Dehalobacter	NA	NA	NA	NA	NA	NA	NA	NA	202	NA	NA	NA	NA
Benzyl Succinante Synthase	0.367 J	NA	NA	NA	NA	NA	NA	NA	0.972 J	NA	NA	NA	NA
Physiological Status (RATIO)													
Decreased Permeability	0.227	NA	NA	NA	NA	NA	NA	NA	0.166	NA	NA	NA	NA
Slowed Growth	2.89	NA	NA	NA	NA	NA	NA	NA	0.734	NA	NA	NA	NA

Notes:

B - Analyte not detected above the level reported in blanks
BD - NO MATCHING QUALIFIER DEFINITION FOUND IN LOOKUP LIST
EB - NO MATCHING QUALIFIER DEFINITION FOUND IN LOOKUP LIST
J - Analyte present. Value may or may not be accurate or precise
NA - Not analyzed
R - Unreliable Result
U - The material was analyed for, but not detected
UJ - Analyte not detected, quantitation limit may be inaccurate
CELLS/ML - Cells per milliliter
GC/ML - Gene copies per milliliter
MG/L - Milligrams per liter
PCT - Percent
RATIO - ratio
UG/L - Micrograms per liter
Shading indicates detection

Appendix B
Soil Boring Logs – July 2008

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PROJECT NUMBER	BORING NUMBER	
378282.FI.FI	SB-20 (Borings 1, 2 & 3)	SHEET 1 OF 3

SOIL BORING LOG

PROJECT : AOC-E FS | LOCATION : AOC-E Vieques, Puerto Rico | DATE: 7/17/2008 - 7/18/2008

WEATHER: Cloudy, ≈ mid 90°F | DRILLING CONTRACTOR : Geo Cim, Inc.

DRILLING METHOD AND EQUIPMENT USED : CME, Trailer Mouned 45C Drilling rig with Automatic Hammer

WATER LEVELS : N/A | START : 7/17/2008 1200hrs | END : 7/18/2008 1505hrs | LOGGER : K. Butler

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (IN) (Boring #)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" [date]	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF PID READING, PID READING, SAMPLE NOMENCLATURE, SAMPLE DATE AND TIME, BORING NUMBER OF READINGS AND SAMPLES — Depth vs ppm / Date:Time / Boring #
	0-2'	14/24 (1st)	Split spoon	7-11-16-11 [7/17]	0-0.4 bgs ORGANIC SOIL (OL/OH) 0.4-1' bgs SILTY GRAVELY SAND (SM), dry, fill 1-4.3' bgs CLAYEY SAND (SC), dry, dark yellowish brown (10YR 4/4), loose, non plastic, non cohesive, fine to medium grained sand	0' bgs = 0.0ppm 1st 1' bgs = 0.0ppm 1st 2' bgs = 0.0ppm 1st
	2-4'	18/24 (1st)	Split Spoon	6-9-9-8 [7/17]		2' bgs = 0.0ppm 1st 3' bgs = 0.0ppm 1st VWAE-SS20-0406-08C 1st 7/17:1300 4' bgs = 0.0ppm 1st
	4-6'	18/24 (1st)	Split Spoon	3-3-4-5 [7/17]	4.3-8' bgs FAT CLAY (CH), strong brown (7.5YR 4/6), dry, medium density, medium to high plasticity, cohesive, with fine to medium grained sand, black mottling	4' bgs = 0.0ppm 1st 5' bgs = 0.0ppm 1st 6' bgs = 0.0ppm 1st
	6-8'	18/24 (1st)	Split Spoon	4-4-5-6 [7/17]		6' bgs = 0.0ppm 1st 6.2' bgs small piece of quartzite (gravel) 6' bgs = 0.6ppm 2nd
	6-8'	19/24 (2nd)	Split spoon	5-5-6-10 [7/18]		7' bgs = 2.5ppm 2nd 8' bgs = 11.9ppm
	8-10'	21/24 (1st)	Split Spoon	2-3-8-5 [7/17]	8-11.6' bgs FAT CLAY (CH), brown (7.5YR 4/3), moist, medium density, high plasticity, cohesive, some fine to medium grained sand, black mottling	8' bgs = 50.3ppm 2nd VWAE-SB20-0810-08C 2nd 7/18:0745
	8-10'	21/24 (2nd)	Split spoon	6-11-18-24 [7/18]		9' bgs = 49.2ppm 2nd 10' bgs = 43.7ppm 2nd
	10-12'	24/24 (1st)	Split Spoon	8-9-13-15 [7/17]		10' bgs = 38.8ppm 2nd
	10-12'	22/24 (2nd)	Split spoon	15-11-12-12 [7/18]	11.6-12.4 ' bgs FAT CLAY (CH), brown (7.5YR 4/3), moist, medium density, high plasticity, cohesive, some fine to medium grained sand, black mottling	11' bgs = 38.2ppm 2nd
	10-12'	(3rd)	Shelby Tube #1			Shelby Tube #1 7/18:1355 3rd 12' bgs =30.5ppm 2nd

Sampler Signature: **K. Butler** Date: **7/18/2008**

PROJECT NUMBER	BORING NUMBER	
378282.FI.FI	SB-20 (Borings 1, 2 & 3)	SHEET 2 OF 3

SOIL BORING LOG

PROJECT : AOC-E FS | LOCATION : AOC-E Vieques, Puerto Rico | DATE: 7/17/2008 - 7/18/2008

WEATHER: Cloudy, ≈ mid 90°F | DRILLING CONTRACTOR : Geo Cim, Inc.

DRILLING METHOD AND EQUIPMENT USED : CME, Trailer Mouned 45C Drilling rig with Automatic Hammer

WATER LEVELS : N/A | START : 7/17/2008 1200hrs | END : 7/18/2008 1505hrs | LOGGER : K. Butler

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (IN) (Boring #)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (n) [date]	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF PID READING, PID READING, SAMPLE NOMENCLATURE, SAMPLE DATE AND TIME, BORING NUMBER OF READINGS AND SAMPLES — Depth vs. ppm Smpl dt:time Boring #
	12-14'	22/24 (1st)	Split spoon	4-5-5-6 [7/17]	11.6-12.4 ' bgs FAT CLAY (CH), brown (7.5YR 4/3), moist, medium density, high plasticity, cohesive, some fine to medium grained sand, black mottling	12' bgs = 17.4ppm 2nd
13	12-14'	22/24	Split spoon	2-3-1-2 [7/18]		13' bgs = 19.2ppm 2nd
14					12.4-14.1' bgs SANDY FAT CLAY (CH), strong brown (7.5YR 4/6), moist, loose, high plasticity, cohesive, fine grained sand coarsening downward, fine black mottling	14' bgs = 16.4ppm 2nd
	14-16'	24/24 (1st)	Split spoon	5-6-5-5 [7/17]	14.1-15.5' bgs FAT CLAY (CH), strong brown (7.5YR 4/6), moist, loose, high plasticity, cohesive	14' bgs = 20.3ppm 2nd
15	14-16'	21/24	Split spoon	1-6-6-6 [7/18]		15' bgs = 23.4ppm
	15-17'	(3rd)	Shelby Tube #2		15.5-19.1' bgs CLAYEY SAND (SC), brown (7.5YR 4/4), moist, loose, non plastic, cohesive, with fine to medium grained sand, coursening downward with gravel at 18.5' bgs	Shelby Tube #2 7/18:1440 3rd
16						16' bgs = 29.8ppm 2nd
	16-18'	18/24 (1st)	Split spoon	3-3-4-5 [7/17]		16' bgs = 30.7ppm VWAE-SB20-1618-08C 7/18:0818 2nd
17	16-18'	24/24	Split spoon	5-6-7-6 [7/18]		17' bgs = 41.0ppm 2nd
18						18' bgs = 28.5ppm 2nd
	18-20'	18/24 (1st)	Split Spoon	4-4-5-6 [7/17]		18' bgs = 4.8ppm 2nd
19	18-20'	21/24 (2nd)	Split spoon	4-6-5-4 [7/18]	19.1-19.5' bgs FAT CLAY (CH), strong brown (7.5YR 4/6), moist, loose, high plasticity, cohesive	19' bgs = 4.3ppm 2nd
20					19.5-20.6' bgs CLAYEY SAND (SC), brown (7.5YR 4/4), moist, loose, non plastic, cohesive, with fine to medium grained sand, coursening downward	20' bgs = 3.8ppm 2nd
	20-22'	21/24 (1st)	Split spoon	2-3-8-5 [7/17]	20.6-21.1' bgs FAT CLAY (CH), strong brown (7.5YR 4/6), moist, loose, high plasticity, cohesive	20' bgs = 3.6ppm 2nd
21	20-22'	24/24 (2nd)	Split spoon	5-7-10-11 [7/18]	21.1-22.3' bgs CLAYEY SAND (SC), brown (7.5YR 4/4), moist, loose, non plastic, cohesive, with fine to medium grained sand, coursening downward	21' bgs = 4.0ppm 2nd
22						22' bgs = 5.0ppm 2nd
	22-24'	24/24 (1st)	Split spoon	8-9-13-13 [7/17]	22.3-25.1' bgs CLAYEY SAND (SC), strong brown (7.5YR 5/6), moist, non plastic, non cohesive, fine to medium grained sand	22' bgs = 1.8ppm 2nd
23	22-24'	23/24 (2nd)	Split spoon	6-7-8-8 [7/18]		23' bgs =1.0ppm 2nd
24						24' bgs = 0.8ppm 2nd

Sampler Signature: **K. Butler** Date: **7/18/2008**

PROJECT NUMBER	BORING NUMBER
378282.FI.FI	SB-20 (Borings 1, 2 & 3) SHEET 3 OF 3

SOIL BORING LOG

PROJECT : AOC-E FS | LOCATION : AOC-E Vieques, Puerto Rico | DATE: 7/17/2008 - 7/18/2008

WEATHER: Cloudy, ≈ mid 90°F | DRILLING CONTRACTOR : Geo Cim, Inc.

DRILLING METHOD AND EQUIPMENT USED : CME, Trailer Mouned 45C Drilling rig with Automatic Hammer

WATER LEVELS : N/A | START : 7/17/2008 1200hrs | END : 7/18/2008 1505hrs | LOGGER : K. Butler

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (IN) (Boring #)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (n) [date]	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF PID READING, PID READING, SAMPLE NOMENCLATURE, SAMPLE DATE AND TIME, BORING NUMBER OF READINGS AND SAMPLES — Depth vs ppm / Smpl dt:time / Boring #
	24-26'	24/24 (1st)	Split Spoon	10-23-35-18 (58x0.6) [7/17]	22.3-25.1' bgs CLAYEY SAND (SC), strong brown (7.5YR 5/6), moist, non plastic, non cohesive, fine to medium grained sand	24' bgs= 0.5ppm 2nd
25	24-26'	23/24 (2nd)	Split Spoon	7-9-14-22 (23x0.6) [7/18]	25.1-25.3' bgs GRAVEL (GW)	25' bgs = 3.0ppm 2nd
26					25.5-26.6' bgs CLAYEY SAND (SC), strong brown (7.5YR 5/6), moist, non plastic, non cohesive, fine to medium grained sand	26' bgs = 4.6ppm 2nd
	26-28'	24/24 (1st)	Split Spoon	13-29-31-23 [7/17]	26.6-28.3' bgs SANDY FAT CLAY (CH), strong brown (7.5YR 4/6), moist, medium plasticity, cohesive, with gravel, fine to coarse grained sand	26' bgs = 8.2ppm 2nd
27	26-28'	24/24 (2nd)	Split Spoon	11-21-32-34 [7/18]		27' bgs = 11.4ppm 2nd
	27-29'	(3rd)	Shelby Tube #3			Shelby Tube #3 7/18:1500 3rd Shelby tube hit refusal 3rd
28						28' bgs = 11.0ppm 2nd
		24/24 (1st)	Split Spoon	12-17-27-33 [7/17]	28.3-34.5' bgs SANDY FAT CLAY (CH), strong brown (7.5YR 5/6), moist, stiff, dense, high plasticity, cohesive, medium grained sand with some fine grained sand, black and grayish green mottling, becomes denser downward	28' bgs = 40.6ppm 2nd VWAE-SB20-2830-08C 7/18:0940
29	28-30'	24/24 (2nd)	Split Spoon	12-20-22-17 [7/18]		29' bgs = 42.1ppm 2nd
30						30' bgs = 42.6ppm 2nd
	30-32'	24/24 (1st)	Split Spoon	10-22-32-37 [7/17]		30' bgs = 1.6ppm 2nd
31	30-32'	24/24 (2nd)	Split Spoon	9-11-16-16 [7/18]		31' bgs = 3.0ppm 2nd
32						32' bgs = 3.2ppm 2nd
	32-34'	24/24 (1st)	Split Spoon	12-36-60-100 [7/17]		32' bgs = 12.8ppm 2nd VWAE-SB20-2830-08C 7/18:1145
33	32-34'	16/17 (2nd)	Split Spoon	23-43-55/5" [7/18]		33' bgs = 15.6 2nd
34						34' bgs = 11.1ppm 2nd
	34-34.5'	5/6 (1st)	Split Spoon	100/5" [7/17]		34' bgs = 13.0ppm 2nd
35	34-34.5'	5/6 (2nd)	Split Spoon	68/6" [7/18]		Terminate borings at 34.5' bgs Total Depth 34.5' bgs
36						

Sampler Signature: **K. Butler** Date: **7/18/2008**

Appendix C
Soil Geotechnical Sampling Results – July 2008

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PTS Laboratories

PTS File No: 38686
Client: CH2M Hill

DRY BULK DENSITY OF IN-PLACE SOIL and TOTAL POROSITY (CALCULATED)

(METHODOLOGY: ASTM D2937, calculation)

PROJECT NAME: Vieques CTO-10 AOC-E&I
PROJECT NO: N/A

SAMPLE ID.	DEPTH, ft.	TOTAL SAMPLE VOLUME, cc	MOISTURE CONTENT, % wt	VOLUMETRIC WATER CONTENT, fraction Vb	DRY BULK DENSITY*, g/cc	TOTAL (1) POROSITY, fraction Vb	VOLUME OF SOLIDS, cc	VOLUME OF VOIDS, cc	VOID RATIO	SATURATION
VWAE-SB21-2022-08C	21.6	439.30	6.6	0.108	1.64	0.378	273.3	166.0	0.607	0.287
VWAE-SB20-1012-08C	11.45	436.80	14.8	0.272	1.84	0.310	301.3	135.5	0.449	0.877
VWAE-SB20-1517-08C	16.35	427.83	9.3	0.158	1.71	0.369	270.0	157.8	0.585	0.430
VWAE-SB21-1012-08C	11.4	407.60	17.6	0.321	1.82	0.306	282.9	124.7	0.441	1.049

* Measured specific gravity used for calculation of bulk density; Water = 0.9986 g/cc; Vb = Bulk Volume; (1) Total Porosity by calculated method

PTS File No: 38686
Client: CH2M Hill

PTS Laboratories

SPECIFIC GRAVITY OF SOILS BY PYCNOMETER

(METHODOLOGY: ASTM D854)

PROJECT NAME: Vieques CTO-10 AOC-E&I
PROJECT NO: N/A

SAMPLE ID.	DEPTH, ft.	TEMPERATURE, °C	TEMPERATURE CORRECTION FACTOR	MASS OF PYCNOMETER AND WATER, grams	MASS OF OVEN DRY SOIL, grams	MASS OF PYCNOMETER, OVEN DRY SOIL, AND WATER, grams	SPECIFIC GRAVITY AT TEMPERATURE	SPECIFIC GRAVITY AT 20°C
VWAE-SB21-2022-08C	20-22	27	0.9983	348.48	90.71	404.9	2.65	2.64
VWAE-SB20-1012-08C	10-12	27	0.9983	352.47	101.99	416.2	2.67	2.66
VWAE-SB20-1517-08C	15-17	27	0.9983	350.09	99.76	413.0	2.71	2.70
VWAE-SB21-1012-08C	10-12	27	0.9983	356.37	103.79	420.7	2.63	2.63

PTS File No: 38686
Client: CH2M Hill

PHYSICAL PROPERTIES DATA - HYDRAULIC CONDUCTIVITY

PROJECT NAME: Vieques CTO-10 AOC-E&I
PROJECT NO: N/A

			METHODS:	API RP 40; ASTM D5084; EPA 9100	
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	CONFINING PRESSURE, psi	EFFECTIVE (2,3) PERMEABILITY TO WATER, millidarcy	HYDRAULIC CONDUCTIVITY (2,3), cm/s
VWAE-SB21-2022-08C	21.9	V	25	6,721	6.76E-03
				6,736	6.78E-03
				6,922	6.97E-03
				6,938	6.98E-03
			Average:	6,829	6.87E-03
VWAE-SB20-1012-08C	11.75	V	25	0.845	8.49E-07
				0.841	8.45E-07
				0.824	8.27E-07
				0.821	8.24E-07
			Average:	0.833	8.36E-07
VWAE-SB20-1517-08C	16.7	V	25	50.8	5.02E-05
				50.0	4.95E-05
				50.5	5.00E-05
				50.7	5.02E-05
			Average:	50.5	4.99E-05
VWAE-SB21-1012-08C	11.7	V	25	0.445	4.41E-07
				0.344	3.41E-07
				0.392	3.88E-07
				0.394	3.91E-07
			Average:	0.394	3.90E-07

(1) Sample Orientation: H = horizontal; V = vertical (2) Native State or Effective = With as-received pore fluids in place (3) Permeability to water and hydraulic conductivity measured at saturated conditions

Vieques - West AOC E
Subsurface Soil Geotechnical Sampling Results
July 2008

Sample ID:	VWAE-SB20-0810-08C	VWAE-SB20-2022-08C	VWAE-SB21-1820-08C	VWAE-SB21-2930-08C
Unit:	%	%	%	%
Geotechnical				
Liquid Limit (LL)	38.00	23.00	22.00	38.00
Plastic Limit (PL)	20.00	16.00	17.00	18.00
Plasticity Index (PI)	18.00	7.00	5.00	20.00
Grain Size (PCT)				
GS01 Sieve 12" (300 mm)	100.00	100.00	100.00	100.00
GS03 Sieve 3" (75 mm)	100.00	100.00	100.00	100.00
GS04 Sieve 2.5" (62.5 mm)	100.00	100.00	100.00	100.00
GS05 Sieve 2" (50 mm)	100.00	100.00	100.00	100.00
GS06 Sieve 1.5" (37.5 mm)	100.00	100.00	100.00	100.00
GS07 Sieve 1" (25.0 mm)	100.00	100.00	100.00	100.00
GS08 Sieve 0.75" (19.0 mm)	100.00	100.00	100.00	100.00
GS09 Sieve 0.5" (12.5 mm)	100.00	100.00	100.00	100.00
GS10 Sieve 0.375" (9.5 mm)	98.60	100.00	100.00	100.00
Sieve No. 004 (4.75 mm)	98.00	98.70	99.40	99.00
Sieve No. 010 (2.00 mm)	95.50	94.50	91.60	97.60
Sieve No. 020 (850 um)	89.20	82.10	65.40	90.10
Sieve No. 040 (425 um)	81.30	68.30	38.70	75.80
Sieve No. 060 (250 um)	75.20	56.90	25.70	64.90
Sieve No. 100 (150 um)	69.60	45.40	17.70	56.80
Sieve No. 200 (75 um)	62.80	34.50	12.90	49.70

Appendix D
Biological Data AOC E - July 2008

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Interpretation of Biological Data and Indicators from Groundwater from AOC E, Vieques, Puerto Rico

PREPARED FOR: Danny Rodriguez/EPA
Wilmarie Rivera/PREQB
Richard Henry/USFWS

PREPARED BY: CH2M HILL, on behalf of the U.S. Navy

COPIES: Kevin Cloe/NAVFAC
Madeline Rivera/NAVFAC
Dan Hood/NAVFAC
Chris Penny/NAVFAC

DATE: December 8, 2008

Introduction

As part of the Remedial Investigation (RI) for the Area of Concern E (AOC E), groundwater samples collected from two monitoring wells (MW-01 and MW-05) on July 28 and 29, 2008 were analyzed for microbial phospholipid fatty acids (PLFA) and deoxyribonucleic acid (DNA) by quantitative polymerase chain reaction (qPCR) to gain insight into the biomass, biological community structure, physiological status, and the presence of selected enzymes and microbes. A groundwater sample was also collected from monitoring well MW-04 for qPCR analysis for the organohalide degrading organism Dehalobacter. This technical memorandum presents a summary and interpretation of the biological data with respect to the potential for biologically supported contaminant degradation (that is, biodegradation). The analytical results associated with this memorandum are presented in Appendix A of the *Technical Memorandum - Proposed Pilot Demonstration of In Situ Remediation at Vieques AOC E* (CH2M HILL, December 2008).

Phospholipid Fatty Acids (PLFA) Analysis

The PLFA are an essential component of intact cell membranes of living cells. The composition of the cell membranes of various microbial communities is so unique that their concentrations and distribution is indicative of not only the total biomass but also the relative population density of major microbial groups in the community. In addition to determining the total biomass and the community structure, PLFA analyses can also provide insight into the physiological status of the Gram-negative bacteria, generally considered to be the dominant biodegradation population.

Biomass

Because PLFA analysis measures essential components of the actual microbial cell, the analysis provides a more accurate measurement of total biomass than traditional

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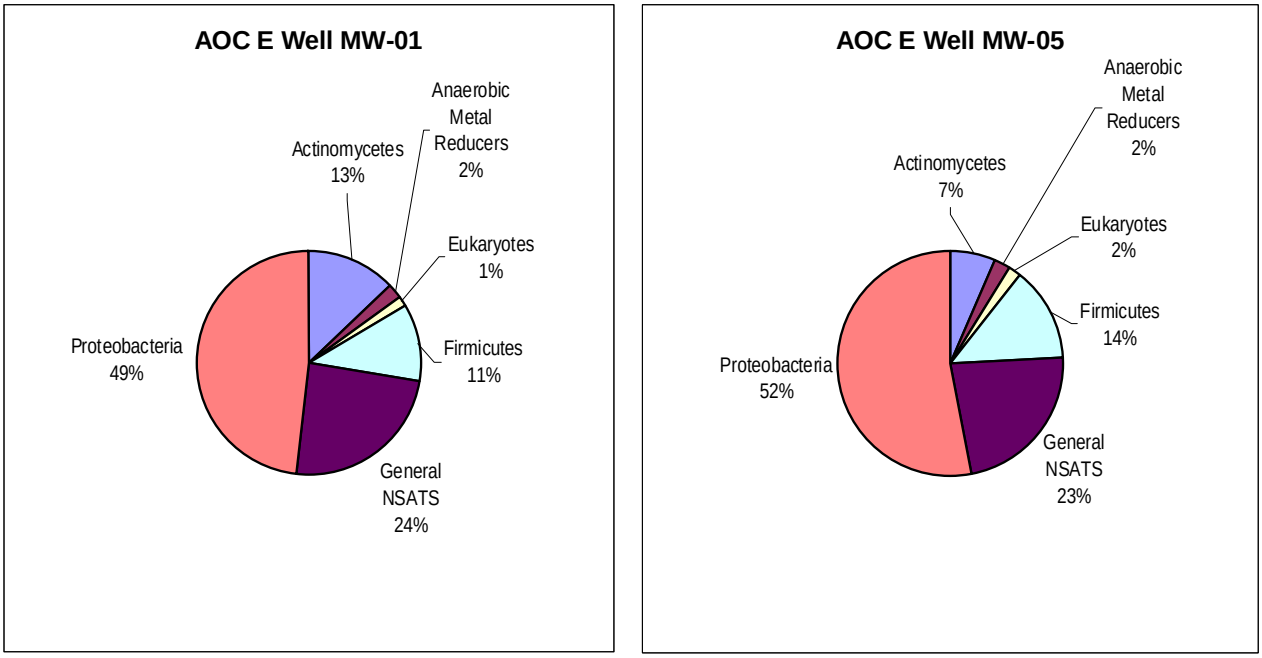
enumeration methods that require microbial growth for counting. Consequently, population densities determined by PLFA are higher than the culture-based methods. PLFA analyses also report groups that are difficult to grow in vitro or when isolated from their microbial consortium. PLFA analysis of groundwater samples from monitoring wells MW-01 and MW-05 indicated a total biomass of 28,300 and 134,000 cells per milliliter (mL), respectively. This is significantly higher than the <1,000 cells/mL typical of un-impacted groundwater, but is considered moderate for in situ groundwater remediation. Optimization of the microbial environment through the addition of nutrients and electron acceptors in a pilot demonstration could increase the biomass, accelerate biodegradation, reduce toxicity, relieve the stress of growth-limiting factors, and foster microbial diversity.

Community Structure

The initial PLFA analysis provides a baseline from which to compare subsequent measurements after enhancement of the biodegradation environment in the subsurface. Exhibit 1 illustrates the community structure found in wells MW-01 and MW-05, respectively.

EXHIBIT 1
Community Structures of Monitoring Wells MW-01 and MW-05 at AOC E



Actinomycetes

The unique metabolic capabilities of the fungal-like bacteria known as the Actinomycetes make them important biodegrading organisms. Actinomycetes provide many of the unique biologically active molecules such as antibiotics, routinely used in medicine. Their presence in the community influences other, competing microbial populations and helps balance the community structure. The group also includes anaerobic sulfate-reducing and iron-reducing bacteria with important biodegradation and energy transfer capabilities. Actinomycetes account for 7 to 13 percent of the microbial population in this formation. They add to both

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the microbial, metabolic diversity and biodegradation capabilities, and their presence attests to the facultative respiratory diversity of the microbial community.

Anaerobic Metal Reducers

Microbes that can utilize oxidized metals such as ferric and manganic ions as electron acceptors play an important role in the energy balance in the anaerobic microbial ecosystem where microbes generally survive in cooperative consortia. The presence of microbes capable of anaerobic metal reduction accounts for, about 2 percent of the microbial population and is consistent with field observations of negative oxidation-reduction potential (ORP) and sample analyses showing concentrations of reduced iron and reduced manganese in monitoring wells MW-01 and MW-05. Their predominant role in energy transfer during anaerobic biodegradation wanes during aquifer conditioning to the aerobic environment needed to expedite the biodegradation of COCs like benzene and MTBE.

Eukaryotes

Eukaryotes are microbes more complex than bacteria, and are generally considered the predators and scavengers of the microbial community. Fungi and protozoans are the typical Eukaryotes found in groundwater systems. By inference, their presence indicates the relative health of the microbial community and reflects the abundance of biomass; increasing concentrations of Eukaryotes indicates a robust, prokaryote population thriving in a biologically supportive environment. Eukaryotes currently account for 1 to 2 percent of the microbial community, but after biostimulation, the prokaryotic microbial community could support a eukaryotic population as high as 3 to 5 percent. While these organisms are not directly associated with the biodegradation of hydrocarbon, their role is critical to the movement of carbon up the microbial food chain.

Firmicutes

Firmicutes are a group of bacteria that lack the secondary outer membrane found in Gram-negative bacteria (such as Proteobacteria, described below). While most Firmicutes have an external cell wall and exhibit a positive or neutral response to Gram staining, some have no cell wall and can not be cultured in vitro using techniques available today. Many bacteria in this group produce spores to survive extreme or unfavorable conditions (such as in-situ chemical oxidation [ISCO]) and selected members biodegrade chlorinated solvents and more complex chlorinated organics like polychlorinated biphenyls (PCBs). Firmicutes account for 11 to 14 percent of the microbial community. Because of their ability to survive extreme conditions, this group is generally the first to re-colonize an environment after chemical oxidation. In some cases, they create the basic biofilms that help support subsequent microbial re-colonization of the aquifer.

General Normal Saturated Straight Chain (NSATS)

NSATS fatty acids are common to all microbial groups. The percentage of general NSATS is an inverse indicator of microbial diversity and a direct indicator of ecological stress. Diversity decreases with increasing levels of NSATS. Microbial ecosystems under stress exhibit less diversity. NSATS account for 23 to 24 percent of the fatty acids found in this aquifer.

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Proteobacteria

Proteobacteria are Gram-negative bacteria with an outer membrane composed of characteristic lipopolysaccharides. Most species in this group are either facultatively or obligately anaerobic and many exhibit a wide range of biodegradation capabilities. Under existing conditions, approximately half the microbes found at the site fall into this group. Proteobacteria account for 49 to 52 percent of the microbial community. Because of broad biodegradation potential, dominance of this population group is indicative of a biologically active system well suited for bioremediation.

Physiological Status of Proteobateria

Proteobacteria under stress alter their membrane structure and membrane permeability by modifying the chemical structure of fatty acids in the membrane. PLFA analysis identifies and quantifies these fatty acids and provides a profile, expressed as a ratio index, indicative of starvation stress or stress due to environmental factors, such as chemical toxicity. The indices express relative measures based on the ratio of one group of fatty acids to another and are not directly related to the traditional, laboratory growth phases of bacterial culture. Exhibit 2 shows the Proteobacteria PLFA stress indices slow growth and decreased permeability along with three ranges of total petroleum hydrocarbons (TPH) data from wells MW-01 and MW-05. Proteobacteria from both wells exhibit the stress indicators but those from well MW-01 exhibited greater stress in both categories than well MW-05 suggesting that the latter community is better adapted to their immediate environment. This observation is supported by the five-fold high level of biomass in well MW-05.

EXHIBIT 2

Proteobacteria PLFA Stress Indicators and Total Petroleum Hydrocarbons Data from Wells MW-04 and MW-07

	MW-01	**MW-05**
Biomass (cells/mL)	**28,300**	**134,000**
Bacterial Slowed Growth **Stress Index** (ratio)	2.89	0.734
Bacterial Decreased Permeability **Stress Index** (ratio)	0.227	0.166
TPH-diesel range (mg/L)	0.29 J	0.56
TPH-gas range (mg/L)	1.4	4.8
TPH-oil range (mg/L)	<1.0 U	2.1

Notes:
cells/mL – cells per milliliter
J – estimated results
mg/L – milligrams per liter
TPH – total petroleum hydrocarbon
ug/L – micrograms per liter
U - Analyzed for, but not detected

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Quantitative Polymerase Chain Reaction (qPCR) of Selected Biomarkers

qPCR is a technique for identifying microbes directly from their DNA and for quantifying specific enzymes in a microbial population. It has the advantage over traditional culturing methods in sensitivity, accuracy, objectivity, and reproducibility. The quantitative analysis can be done on uncultured bacteria, thereby eliminating the need for a pure culture, special growth requirements, growth conditions, and preliminary testing. The presences of key enzymes that activate the initial step in a degradation pathway are considered strong evidence of microbial capabilities for biodegradation potential at a specific site. For aromatic hydrocarbon degradation in an anaerobic environment, Benzylsuccinate Synthase (BSSA) is generally considered indicative of a microbial community's biodegradation potential.

For the AOC E groundwater samples, qPCR was used to detect the presence of Dehalobacter species, an important biodegradation microbe, and to quantify the presence of the functional anaerobic enzyme gene BSSA.

Indicator Microorganisms: Dehalobacter (qDHB)

Assuming one gene copy per cell, about 0.15 percent of the biomass in well MW-05 is accounted for by Dehalobacter species, an obligate anaerobe capable of biodegrading tetrachloroethylene (PCE) to ethene and chloride by dehalorespiration. Detection of these organisms indicates a latent capability for bioremediation that may be dependent on optimization of the environment with nutrients and electron donors/electron acceptors.

Functional Gene: Benzylsuccinate Synthase (BSSA)

BSSA mediated catalysis of toluene and formate to form benzylsuccinate is the initial activation reaction of anaerobic oxidation of the aromatic hydrocarbons toluene and ethylbenzene by anaerobic bacteria. This highly oxygen sensitive enzyme is commonly associated with sulfate reducing bacteria. BSSA is the key enzyme of anaerobic toluene degradation and has been found in all anaerobic toluene degrading bacterial isolates tested. The discovery of significant amounts of BSSA indicates the presence of toluene degrading microbes functioning under anaerobic conditions.

Summary

Both the PLFA analysis and the qPCR data support the presence of significant but latent biodegradation capability. PLFA analyses reported a moderate microbial population of 28,300 and 134,000 cells/mL. The microbial ecosystem in both wells is under environmental stress as indicated by the following three indicators:

- The percentage of general NSATS relative to other groups of fatty acids suggests limited diversity, an indicator of environmental stress
- Slow growth associated with starvation conditions
- Limited membrane permeability

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An abundance of Gram-negative biodegrading organisms prevails along with potential biodegraders from other groups. The percentage of predatory/scavenger Eukaryotes is currently low in both wells.

qPCR reported Dehalobacter species and revealed that the prevailing anaerobic conditions supported expression of BSSA gene, the key enzyme responsible for the initial activation reaction of anaerobic degradation of the aromatic hydrocarbons toluene and ethylbenzene.

Recommendations and Expectations

This aquifer exhibits strong potential for biodegradation; however, higher levels of biomass, lower levels of stress, and greater diversity could be enhanced by optimizing the environment. Consider implementing a pilot demonstration to enhance in situ biodegradation by delivering growth and metabolism limiting factors to the aquifer. Conduct additional PLFA and qPCR analyses after enhancing bio-attenuation conditions through aquifer conditioning and following the addition of electron acceptors and nutrients during a pilot study. Re-evaluation of the biological indicators and markers after the system is adjusted to aerobic conditions should reveal the following:

- Increase in quantities of the aerobic functional gene naphthalene dioxygenase
- Elimination of anaerobic BSSA functional gene
- Increase in microbial diversity as evidenced by a decrease in the percentage of general NSATS relative to other community members.
- Reduction or elimination of the stress indicators of starvation and limited membrane permeability
- Ultimately a gross reduction in the total biomass to approach that of the un-impacted aquifer

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Appendix E
MSDS for ISCO and EISB Reagents

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MATERIAL SAFETY DATA SHEET

Dissolvine® E-FE-13

MSDS Ref. No.: 15708-41-5
Date Approved: 01/17/2006
Revision No.: 1

This document has been prepared to meet the requirements of the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200; the Canada's Workplace Hazardous Materials Information System (WHMIS) and, the EC Directive, 2001/58/EC.

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:	Dissolvine® E-FE-13
MOLECULAR FORMULA:	$C_{10}H_{12}FeN_2O_8Na \cdot 3H_2O$
SYNONYMS:	Ferric sodium EDTA; CHEMICAL NAME: Ethylenediaminetetraacetic acid, ferric sodium complex
GENERAL USE:	Chelating agent / Plant nutrient

NOTE: This product is not defined and regulated as a hazardous substance. Handle in accordance with good industrial hygiene practices.

MANUFACTURER

Akzo Nobel Functional Chemicals LLC
525 West Van Buren Street
Chicago, IL 60607-3823

Product & Technical Information:
(800) 906-7979 (U.S.A.)
(312) 544-7000 (outside of U.S.A.)

EMERGENCY TELEPHONE NUMBERS

(914) 693-6946 (Akzo Nobel - U.S.A.)

For leak, fire, spill, or accident emergencies, call:
(800) 424-9300 (CHEMTREC - U.S.A.)
(703) 527-3887 (CHEMTREC - All Other Countries)
(613) 996-6666 (CANUTEC - Canada)

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:

- Yellow-green odorless powder.
- CAUTION: Contact with dust may cause discomfort and/or mild irritation.

POTENTIAL HEALTH EFFECTS: Effects from overexposure may occur from inhaling, or coming into contact with skin or eyes. Acute exposure to excessive concentrations of dust may cause respiratory tract discomfort and/or mild irritation. Eye contact with dust may cause mild physical irritation.

MEDICAL CONDITIONS AGGRAVATED: No data available.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS#	Wt.%	EC No.	EC Class
EDTA, ferric sodium complex	15708-41-5	87 - 89	239-802-2	Not classified
Water	7732-18-5	11 - 13	231-791-2	Not classified

4. FIRST AID MEASURES

EYES: Flush with large quantities of water for at least 15 minutes, lifting the upper and lower eyelids intermittently. If wearing contact lenses, remove after the first five minutes and continue flushing with water. If irritation occurs and persists, get medical attention.

SKIN: Immediately flush with plenty of water while removing contaminated clothing and/or shoes, and thoroughly wash with soap and water. If irritation occurs and persists, obtain medical attention.

INGESTION: Give several glasses of water if able to swallow. DO NOT induce vomiting. If vomiting occurs, keep head below hips to reduce the risk of aspiration. Never give anything by mouth to an unconscious or convulsing person. Get medical attention if health effects occur.

INHALATION: Remove to fresh air. If breathing difficulty or discomfort occurs and persists, see a medical doctor. If breathing has stopped, give artificial respiration and see a medical doctor immediately.

NOTES TO MEDICAL DOCTOR: This product has a low order of toxicity and is considered to be practially harmless by ingestion. Treatment is symptomatic and supportive.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA: Foam, CO_2 or dry chemical. Soft stream water fog only if necessary. Contain all runoff.

FIRE / EXPLOSION HAZARDS: This product is not defined as flammable or combustible. When involved in a fire, it does not contribute any unusual hazards.

FIRE FIGHTING PROCEDURES: As in any fire, prevent human exposure to fire, smoke, fumes or products of combustion. Evacuate all non-essential personnel from the fire area. Fire-fighters should wear full-face, self-contained breathing apparatus and impervious protective clothing.

FLAMMABLE LIMITS: Upper / Lower (% by volume): Not determined

SENSITIVITY TO IMPACT: It is not self-reactive and is not sensitive to impact under typical conditions of use, storage or transport.

COMMENTS: CONDITIONS OF FLAMMABILITY: Not flammable or combustible.

6. ACCIDENTAL RELEASE MEASURES

RELEASE NOTES: Keep material out of streams and sewers. Large spills should be covered to prevent dispersal. For dry material, use a wet sweeping compound or water to prevent the formation of dust. If water is used, prevent runoff or dispersion of excess liquid by diking and absorbing with a non-combustible absorbent such as clay, sand or soil. Vacuum, shovel or pump waste into a drum and label contents for disposal.

Restrict non-essential personnel from area. All personnel involved in spill cleanup should follow good industrial hygiene practices and avoid skin and eye contact by wearing appropriate personal protective equipment, as indicated in Section 8 (Exposure Controls / Personal Protection) below.

7. HANDLING AND STORAGE

HANDLING: Containers should not be opened until ready for use. Avoid inhalation and prolonged and/or repeated skin and eye contact. Minimize generation of dust.

STORAGE: Store in a cool, dry place at an ambient temperature (below 25ºC / 77ºF). This material is suitable for any general chemical storage area; however, store in PVC, PE, stainless steel or bituminized tanks. Isolate from strong oxidizing agents and avoid contact with aluminum, copper, copper allows and nickel.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS: Under normal use conditions, special ventilation is usually not required; however, ensure that existing ventilation is sufficient to prevent the circulation and/or accumulation of dust in the air.

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: Wear dust-tight goggles when handling this product.

RESPIRATORY: For dust exposures, wear a NIOSH-approved half-mask, air-purifying respirator with dust, mist and fume filters to reduce the potential for inhalation exposure. When using respirator cartridges or canisters, they must be changed frequently (following each use or at the end of the work shift) to assure breakthrough exposure does not occur.

PROTECTIVE CLOTHING: Wear suitable protective clothing and footwear in accordance with use and exposure potential.

GLOVES: Wear gloves that are in accordance with use and exposure potential. Wash the outside of gloves with soap and water prior to removal. Inspect regularly for leaks.

WORK HYGIENIC PRACTICES: Clean water should be available for washing in case of eye or skin contamination. All food and smoking materials should be kept in a separate area away from the storage / use location. Eating, drinking and smoking should be prohibited in areas where there is a potential for significant exposure to this material. Wash skin prior to eating, drinking or using tobacco. Shower at the end of the workday.

COMMENTS:

EXPOSURE LIMITS:

Particulates Not Otherwise Classified (PNOC):
ACGIH / TWA: 10 mg/m^3 (inhalable particulate); 3 mg/m^3 (respirable particulate)
OSHA (PEL / TWA): 15 mg/m^3 (total dust); 5 mg/m^3 (resp fraction)

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9. PHYSICAL AND CHEMICAL PROPERTIES

ODOR:	Odorless
APPEARANCE:	Yellow-green powder
AUTOIGNITION TEMPERATURE:	Not applicable
BOILING POINT:	Not applicable
COEFFICIENT OF OIL / WATER:	Not determined.
DENSITY / WEIGHT PER VOLUME:	(Bulk) ~ 650 kg/m^3
EVAPORATION RATE:	(Butyl Acetate = 1) Not determined
FLASH POINT:	Not applicable
MELTING POINT:	80ºC (176ºF) / crystal water loss
ODOR THRESHOLD:	Not determined.
PERCENT VOLATILE:	(% by weight) Not determined

pH:	~ 4.0 - 5.5 (1% solution)
SOLUBILITY IN WATER:	90 g/L (at 20ºC / 68ºF); 300 g/L (at 80ºC / 176ºF)
SPECIFIC GRAVITY:	(H_2O=1) Not determined
VAPOR DENSITY:	(Air = 1) Not determined
VAPOR PRESSURE:	Not applicable
VISCOSITY:	Not determined.

10. STABILITY AND REACTIVITY

STABILITY:	Stable at ambient temperatures and atmospheric pressures.
POLYMERIZATION:	Not expected under normal temperatures and pressure.
INCOMPATIBLE MATERIALS:	Aqueous solution in contact with aluminum evolves hydrogen. This product is incompatible with strong oxidizers. Avoid contact with aluminum, copper, copper alloys and nickel. Avoid prolonged storage at elevated temperatures.
HAZARDOUS DECOMPOSITION PRODUCTS:	Under fire conditions this product may support combustion and decomposes to give off carbon mon/dioxide fumes (CO, CO2) and nitrogen oxides. Decomposition Temperature: 180 ± 20ºC (356 ± 36ºF)

COMMENTS: HAZARDOUS COMBUSTION PRODUCTS: Thermal decomposition products may release toxic and/or hazardous fumes and gases, including nitrogen oxides and carbon oxides.

11. TOXICOLOGICAL INFORMATION

EYE EFFECTS: Expected to be minimally irritating.

SKIN EFFECTS: Expected to be slightly irritating.

DERMAL LD_{50}: No data available.

ORAL LD_{50}: Similar product: > 2,000 mg/kg (rat)

INHALATION LC_{50}: No data available.

SENSITIZATION: No data available.

TARGET ORGANS: Eyes, skin

ACUTE EFFECTS FROM OVEREXPOSURE: This product has a low order of toxicity and is considered to be practially harmless by ingestion. Ferric sodium EDTA has shown slight transient conjunctivitis and corneal opacity in rabbits. No additional acute toxicological information is known.

CHRONIC EFFECTS FROM OVEREXPOSURE: Ingestion of up to 86.15 mg/kg/day of ferric sodium EDTA for 31 to 61 days by rats resulted in an accumulation of iron in the liver, spleen and kidneys. There were no abnormal necropsy or histopathology findings.

Ferric sodium EDTA, when tested as a pure substance, gave a negative response in the Ames Assay and the E. Coli bacterial reverse assay, but a positive response in the Mouse Lymphoma Assay (in vitro) with and without metabolic activation at concentrations which were cytotoxic The positive response was attributed to a possible sensitivity of the cells to abnormal iron concentrations.

EDTA and its sodium salts have been reported, in some studies, to cause developmental toxicity in laboratory animals only at exaggerated doses that were toxic to the mother. These effects are likely associated with zinc deficiency due to chelation. Exposures having no effect on the zinc level of the mother, should have no effect on the fetus.

CARCINOGENICITY:

NTP:	Not listed
IARC:	Not listed
OSHA:	Not listed
OTHER:	Not Listed (ACGIH)

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL DATA: Ferric sodium EDTA was biodegradable when evaluated using a mixed population of aerated bacteria. Ferric sodium EDTA component is not likely to bioaccumulate due to its high water solubility and a Log Pow equal to -10.6 (based on EPIWIN model).

ECOTOXICOLOGICAL INFORMATION: Ferric sodium EDTA showed low toxicity to fish (96-hour LC_{50} = 8100 mg/L for a 32% solution and 2592 mg/L for a 100% active), and moderate toxicity to algae (72-hour LC_{50} = 76.7 mg/L).

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: In its unused condition, this product is not considered to be a RCRA-defined hazardous waste by characteristics or listings. It is the responsibility of the waste generator to evaulate whether the waste is hazardous by characteistic or listing. Dispose as a hazardous waste in

accordance with local, state and federal regulatory agencies. NOTE: State and local regulations may be more stringent than federal regulations.

EMPTY CONTAINER: Containers which held this material should be triple-rinsed prior to disposal or return. Empty containers should be disposed of, or shipped, in accordance with all applicable laws and regulations.

14. TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION (DOT)

ADDITIONAL INFORMATION: This material is not a hazardous material as defined by US Department of Transportation at 49 CFR Parts 100 through 185.

INTERNATIONAL MARITIME DANGEROUS GOODS (IMDG)

ADDITIONAL INFORMATION: This material is not a dangerous good as defined by the International Maritime Dangerous Goods Code.

ADR - EUROPEAN AGREEMENT CONCERNING THE INTERNATIONAL CARRIAGE OF DANGEROUS GOODS BY ROAD

ADDITIONAL INFORMATION: This material is not a dangerous good as defined by ADR.

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) / INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)

ADDITIONAL INFORMATION: This material is not a dangerous good as defined in ICAO and the International Air Transport Association Dangerous Goods Regulations.

OTHER INFORMATION:

REQUIRED LABELS: No transport label required.

ENVIRONMENTALLY HAZARDOUS SUBSTANCES (49 CFR 172.101, Appendix A): None

15. REGULATORY INFORMATION

UNITED STATES

SARA TITLE III (SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT)

SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355, APPENDIX A):
Not regulated

SECTION 312 THRESHOLD PLANNING QUANTITY (40 CFR 370):
The Threshold Planning Quantity (TPQ) for this product, if treated as a mixture, is 10,000 lbs; however, this product contains the following ingredients with a TPQ of less than 10,000 lbs.:
Not regulated

SECTION 313 REPORTABLE INGREDIENTS (40 CFR 372):
Not regulated

CERCLA (COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION AND LIABILITY ACT)

CERCLA DESIGNATION & REPORTABLE QUANTITIES (RQ) (40 CFR 302.4):
Not regulated

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA INVENTORY STATUS (40 CFR 710):
Listed (components)

U.S. STATES

California Prop 65:
Not regulated
U.S. State Regulation:
Not regulated

CANADA

WHMIS (WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM):

Not a controlled product under the Canadian Workplace Hazardous Materials Information System (WHMIS).

Domestic Substance List: Listed (components)

INTERNATIONAL LISTINGS

EDTA, ferric sodium
Australia (AICS): Listed
China: Listed

Japan (ENCS): (2)-1266
Korea: KE-31512
Philippines (PICCS): Listed

Water
Australia (AICS): Listed
China: Listed
Korea: KE-35400
Philippines (PICCS): Listed

16. OTHER INFORMATION

HMIS

Health	1
Flammability	1
Physical Hazard	0
Personal Protection (PPE)	None

No special requirements

HMIS = Hazardous Materials Identification System

Degree of Hazard Code:
4 = Severe
3 = Serious
2 = Moderate
1 = Slight
0 = Minimal

NFPA

Health	1
Flammability	0
Reactivity	0
Special	None

No special requirements

NFPA = National Fire Protection Association

Degree of Hazard Code:
4 = Extreme
3 = High
2 = Moderate
1 = Slight
0 = Insignificant

REVISION SUMMARY:
New MSDS.

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MATERIAL SAFETY DATA SHEET

Klozür™

MSDS Ref. No.: 7775-27-1-12
Date Approved: 02/22/2005
Revision No.: 1

This document has been prepared to meet the requirements of the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200; the Canada's Workplace Hazardous Materials Information System (WHMIS) and, the EC Directive, 2001/58/EC.

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:	Klozür™
SYNONYMS:	Sodium Persulfate, Sodium Peroxydisulfate; Disodium Peroxydisulfate
GENERAL USE:	In situ and ex situ chemical oxidation of contaminants and compounds of concern for environmental remediation applications.

MANUFACTURER

FMC CORPORATION
Active Oxidants Division
1735 Market Street
Philadelphia, PA 19103
(215) 299-6000 (General Information)

EMERGENCY TELEPHONE NUMBERS

(800) 424-9300 (CHEMTREC - U.S.)
(303) 595-9048 (Medical - Call Collect)

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:

- White, odorless, crystals
- Oxidizer.
- Decomposes in storage under conditions of moisture (water/water vapor) and/or excessive heat causing release of oxides of sulfur and oxygen that supports combustion. Decomposition could form a high temperature melt. See Section 10 ("Stability and Reactivity").

POTENTIAL HEALTH EFFECTS: Airborne persulfate dust may be irritating to eyes, nose, lungs, throat and skin upon contact. Exposure to high levels of persulfate dust may cause difficulty in breathing in sensitive persons.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS#	Wt.%	EC No.	EC Class
Sodium Persulfate	7775-27-1	>99	231-892-1	Not classified as hazardous

4. FIRST AID MEASURES

EYES: Flush with plenty of water. Get medical attention if irritation occurs and persists.

SKIN: Wash with plenty of soap and water. Get medical attention if irritation occurs and persists.

INGESTION: Rinse mouth with water. Dilute by giving 1 or 2 glasses of water. Do not induce vomiting. Never give anything by mouth to an unconscious person. See a medical doctor immediately.

INHALATION: Remove to fresh air. If breathing difficulty or discomfort occurs and persists, contact a medical doctor.

NOTES TO MEDICAL DOCTOR: This product has low oral toxicity and is not irritating to the eyes and skin. Flooding of exposed areas with water is suggested, but gastric lavage or emesis induction for ingestions must consider possible aggravation of esophageal injury and the expected absence of system effects. Treatment is controlled removal of exposure followed by symptomatic and supportive care.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA: Deluge with water.

FIRE / EXPLOSION HAZARDS: Product is non-combustible. On decomposition releases oxygen which may intensify fire. Presence of water accelerates decomposition.

FIRE FIGHTING PROCEDURES: Do not use carbon dioxide or other gas filled fire extinguishers; they will have no effect on decomposing persulfates. Wear full protective clothing and self-contained breathing apparatus.

FLAMMABLE LIMITS: Non-combustible

SENSITIVITY TO IMPACT: No data available

SENSITIVITY TO STATIC DISCHARGE: Not available

6. ACCIDENTAL RELEASE MEASURES

RELEASE NOTES: Spilled material should be collected and put in approved DOT container and isolated for disposal. Isolated material should be monitored for signs of decomposition (fuming/smoking). If spilled material is wet, dissolve with large quantity of water and dispose as a hazardous waste. All disposals should be carried out according to regulatory agencies procedures.

7. HANDLING AND STORAGE

HANDLING: Use adequate ventilation when transferring product from bags or drums. Wear respiratory protection if ventilation is inadequate or not available. Use eye and skin protection. Use clean plastic or stainless steel scoops only.

STORAGE: Store (unopened) in a cool, clean, dry place away from point sources of heat, e.g. radiant heaters or steam pipes. Use first in, first out storage system. Avoid contamination of opened product. In case of fire or decomposition (fuming/smoking) deluge with plenty of water to control decomposition. For storage, refer to NFPA Bulletin 430 on storage of liquid and solid oxidizing materials.

COMMENTS: VENTILATION: Provide mechanical general and/or local exhaust ventilation to prevent release of dust into work environment. Spills should be collected into suitable containers to prevent dispersion into the air.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMITS

Chemical Name	ACGIH	OSHA	Supplier
Sodium Persulfate	0.1 mg/m^3 (TWA)		

ENGINEERING CONTROLS: Provide mechanical local general room ventilation to prevent release of dust into the work environment. Remove contaminated clothing immediately and wash before reuse.

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: Use cup type chemical goggles. Full face shield may be used.

RESPIRATORY: Use approved dust respirator when airborne dust is expected.

PROTECTIVE CLOTHING: Normal work clothes. Rubber or neoprene footwear.

GLOVES: Rubber or neoprene gloves. Thoroughly wash the outside of gloves with soap and water prior to removal. Inspect regularly for leaks.

9. PHYSICAL AND CHEMICAL PROPERTIES

ODOR:	None
APPEARANCE:	White crystals
AUTOIGNITION TEMPERATURE:	Not applicable. No evidence of combustion up to 800°C. Decomposition will occur upon heating.
BOILING POINT:	Not applicable
COEFFICIENT OF OIL / WATER:	Not applicable
DENSITY / WEIGHT PER VOLUME:	Not available
EVAPORATION RATE:	Not applicable (Butyl Acetate = 1)
FLASH POINT:	Non-combustible
MELTING POINT:	Decomposes
ODOR THRESHOLD:	Not applicable
OXIDIZING PROPERTIES:	Oxidizer
PERCENT VOLATILE:	Not applicable
pH:	typically 5.0 - 7.0 @ 25 °C (1% solution)
SOLUBILITY IN WATER:	73 % @ 25 °C (by wt.)
SPECIFIC GRAVITY:	2.6 (H_2O=1)
VAPOR DENSITY:	Not applicable (Air = 1)
VAPOR PRESSURE:	Not applicable

10. STABILITY AND REACTIVITY

CONDITIONS TO AVOID:	Heat, moisture and contamination.
STABILITY:	Stable (becomes unstable in presence of heat, moisture and/or contamination).
POLYMERIZATION:	Will not occur
INCOMPATIBLE MATERIALS:	Acids, alkalis, halides (fluorides, chlorides, bromides and iodides), combustible materials, most metals and heavy metals, oxidizable materials, other oxidizers, reducing agents, cleaners, and organic or carbon containing compounds. Contact

with incompatible materials can result in a material decomposition or other uncontrolled reactions.

HAZARDOUS DECOMPOSITION PRODUCTS: Oxygen that supports combustion and oxides of sulfur.

COMMENTS: PRECAUTIONARY STATEMENT: Pumping and transport of Klozür persulfate requires appropriate precautions and design considerations for pressure and thermal relief.

Decomposing persulfates will evolve large volumes of gas and/or vapor, can accelerate exponentially with heat generation, and create significant and hazardous pressures if contained and not properly controlled or mitigated.

Use with alcohols in the presence of water has been demonstrated to generate conditions that require rigorous adherence to process safety methods and standards to prevent escalation to an uncontrolled reaction.

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11. TOXICOLOGICAL INFORMATION

EYE EFFECTS: Non-irritating (rabbit) [FMC Study Number: ICG/T-79.029]

SKIN EFFECTS: Non-irritating (rabbit) [FMC Study Number: ICG/T-79.029]

DERMAL LD_{50}: > 10 g/kg [FMC Study Number: ICG/T-79.029]

ORAL LD_{50}: 895 mg/kg (rat) [FMC Study Number: ICG/T-79.029]

INHALATION LC_{50}: 5.1 mg/l (rat) [FMC I95-2017]

SENSITIZATION: May be sensitizing to allergic persons. [FMC Study Number: ICG/T-79.029]

TARGET ORGANS: Eyes, skin, respiratory passages

ACUTE EFFECTS FROM OVEREXPOSURE: Dust may be harmful and irritating. May be harmful if swallowed.

CHRONIC EFFECTS FROM OVEREXPOSURE: Sensitive persons may develop dermatitis and asthma [Respiration 38:144, 1979]. Groups of male and female rats were fed 0, 300 or 3000 ppm sodium persulfate in the diet for 13 weeks, followed by 5000 ppm for 5 weeks. Microscopic examination of tissues revealed some injury to the gastrointestinal tract at the high dose (3000 ppm) only. This effect is not unexpected for an oxidizer at high concentrations. [Ref. FMC I90-1151, Toxicologist 1:149, 1981].

CARCINOGENICITY:

NTP:	Not listed
IARC:	Not listed
OSHA:	Not listed
OTHER:	ACGIH: Not listed

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION:

Bluegill sunfish, 96-hour LC_{50} = 771 mg/L [FMC Study I92-1250]
Rainbow trout, 96-hour LC_{50} = 163 mg/L [FMC Study I92-1251]
Daphnia, 48-hour LC_{50} = 133 mg/L [FMC Study I92-1252]
Grass shrimp, 96-hour LC_{50} = 519 mg/L [FMC Study I92-1253]

CHEMICAL FATE INFORMATION: Biodegradability does not apply to inorganic substances.

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose as a hazardous waste in accordance with local, state and federal regulatory agencies.

14. TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION (DOT)

PROPER SHIPPING NAME:	Sodium Persulfate
PRIMARY HAZARD CLASS / DIVISION:	5.1 (Oxidizer)
UN/NA NUMBER:	UN 1505
PACKING GROUP:	III
LABEL(S):	5.1 (Oxidizer)
PLACARD(S):	5.1 (Oxidizer)
MARKING(S):	Sodium Persulfate, UN 1505
ADDITIONAL INFORMATION:	Hazardous Substance/RQ: Not applicable

49 STCC Number: 4918733

This material is shipped in 225 lb. fiber drums, 55 lb. poly bags and 1000 - 2200 lb. IBC's (supersacks).

INTERNATIONAL MARITIME DANGEROUS GOODS (IMDG)

PROPER SHIPPING NAME: Sodium Persulfate

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) / INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)

PROPER SHIPPING NAME: Sodium Persulfate

OTHER INFORMATION:

Protect from physical damage. Do not store near acids, moisture or heat.

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15. REGULATORY INFORMATION

UNITED STATES

SARA TITLE III (SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT)

SECTION 302 EXTREMELY HAZARDOUS SUBSTANCES (40 CFR 355, APPENDIX A):
Not applicable

SECTION 311 HAZARD CATEGORIES (40 CFR 370):
Fire Hazard, Immediate (Acute) Health Hazard

SECTION 312 THRESHOLD PLANNING QUANTITY (40 CFR 370):
The Threshold Planning Quantity (TPQ) for this product, if treated as a mixture, is 10,000 lbs; however, this product contains the following ingredients with a TPQ of less than 10,000 lbs.: None

SECTION 313 REPORTABLE INGREDIENTS (40 CFR 372):
Not listed

CERCLA (COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION AND LIABILITY ACT)

CERCLA DESIGNATION & REPORTABLE QUANTITIES (RQ) (40 CFR 302.4):
Unlisted, RQ = 100 lbs., Ignitability

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA INVENTORY STATUS (40 CFR 710):

Listed

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)
RCRA IDENTIFICATION OF HAZARDOUS WASTE (40 CFR 261):
Waste Number: D001

CANADA

WHMIS (WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM):

Product Identification Number: 1505
Hazard Classification / Division: Class C (Oxidizer), Class D, Div. 2, Subdiv. B. (Toxic)
Ingredient Disclosure List: Listed

INTERNATIONAL LISTINGS

Sodium persulfate:
Australia (AICS): Listed
China: Listed
Japan (ENCS): (1)-1131
Korea: KE-12369
Philippines (PICCS): Listed

HAZARD, RISK AND SAFETY PHRASE DESCRIPTIONS:

EC Symbols: (Not classified as hazardous)

EC Risk Phrases: (Not classified as hazardous)

EC Safety Phrases: (Not classified as hazardous)

16. OTHER INFORMATION

HMIS

Health	1
Flammability	0
Physical Hazard	1
Personal Protection (PPE)	J

Protection = J (Safety goggles, gloves, apron & combination dust & vapor respirator)

HMIS = Hazardous Materials Identification System

Degree of Hazard Code:
4 = Severe

3 = Serious
2 = Moderate
1 = Slight
0 = Minimal

NFPA

Health	1
Flammability	0
Reactivity	1
Special	OX

SPECIAL = OX (Oxidizer)

NFPA = National Fire Protection Association

Degree of Hazard Code:
4 = Extreme
3 = High
2 = Moderate
1 = Slight
0 = Insignificant

REVISION SUMMARY:
New MSDS

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Oxygen Release Compound – Advanced (ORC *Advanced*™)
MATERIAL SAFETY DATA SHEET (MSDS)

Last Revised: March 13, 2007

Section 1 - Material Identification

Supplier:

REGENESIS

1011 Calle Sombra
San Clemente, CA 92673

Phone:	**949.366.8000**
Fax:	**949.366.8090**
E-mail:	**info@regenesis.com**

Chemical Description:	A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
Chemical Family:	Inorganic Chemical
Trade Name:	Advanced Formula Oxygen Release Compound (ORC *Advanced*™)
Chemical Synonyms	Calcium Hydroxide Oxide; Calcium Oxide Peroxide
Product Use:	Used to remediate contaminated soil and groundwater (environmental applications)

Section 2 – Composition

CAS No.	Chemical
682334-66-3	**Calcium Hydroxide Oxide [$CaO(OH)_2$]**
1305-62-0	**Calcium Hydroxide [$Ca(OH)_2$]**
7758-11-4	**Dipotassium Phosphate (HK_2O_4P)**
7778-77-0	**Monopotassium Phosphate (H_2KO_4P)**

Section 3 – Physical Data	
Form:	Powder
Color:	White to Pale Yellow
Odor:	Odorless
Melting Point:	527 °F (275 °C) – Decomposes
Boiling Point:	Not Applicable (NA)
Flammability/Flash Point:	NA
Auto- Flammability:	NA
Vapor Pressure:	NA
Self-Ignition Temperature:	NA
Thermal Decomposition:	527 °F (275 °C) – Decomposes
Bulk Density:	0.5 – 0.65 g/ml (Loose Method)
Solubility:	1.65 g/L @ 68° F (20° C) for calcium hydroxide.
Viscosity:	NA
pH:	11-13 (saturated solution)
Explosion Limits % by Volume:	Non-explosive
Hazardous Decomposition Products:	Oxygen, Hydrogen Peroxide, Steam, and Heat
Hazardous Reactions:	None

Section 4 – Reactivity Data

Stability:	Stable under certain conditions (see below).
Conditions to Avoid:	Heat and moisture.
Incompatibility:	Acids, bases, salts of heavy metals, reducing agents, and flammable substances.
Hazardous Polymerization:	Does not occur.

Section 5 – Regulations

TSCA Inventory List:	Listed

CERCLA Hazardous Substance (40 CFR Part 302)

Listed Substance:	No
Unlisted Substance:	Yes
Reportable Quantity (RQ):	100 pounds
Characteristic(s):	Ignitibility
RCRA Waste Number:	D001

SARA, Title III, Sections 302/303 (40 CFR Part 355 – Emergency Planning and Notification)

Extremely Hazardous Substance:	No

SARA, Title III, Sections 311/312 (40 CFR Part 370 – Hazardous Chemical Reporting: Community Right-To-Know

Hazard Category:	Immediate Health Hazard Fire Hazard
Threshold Planning Quantity:	10,000 pounds

Section 5 – Regulations (cont)

SARA, Title III, Section 313 (40 CFR Part 372 – Toxic Chemical Release Reporting: Community Right-To-Know

Extremely Hazardous Substance:	No	
WHMIS Classification:	C	Oxidizing Material Poisonous and Infectious Material
	D	Material Causing Other Toxic Effects – Eye and Skin Irritant
Canadian Domestic Substance List:	Not Listed	

Section 6 – Protective Measures, Storage and Handling

Technical Protective Measures

Storage:	Keep in tightly closed container. Store in dry area, protected from heat sources and direct sunlight.
Handling:	Clean and dry processing pipes and equipment before operation. Never return unused product to the storage container. Keep away from incompatible products. Containers and equipment used to handle this product should be used exclusively for this material. Avoid contact with water or humidity.

Section 6 – Protective Measures, Storage and Handling (cont)

Personal Protective Equipment (PPE)

Engineering Controls:	Calcium Hydroxide ACGIH® TLV® (2000) 5 mg/m^3 TWA OSHA PEL Total dust–15 mg/m^3 TWA Respirable fraction– 5 mg/m^3 TWA NIOSH REL (1994) 5 mg/m^3
Respiratory Protection:	For many conditions, no respiratory protection may be needed; however, in dusty or unknown atmospheres use a NIOSH approved dust respirator.
Hand Protection:	Impervious protective gloves made of nitrile, natural rubbber or neoprene.
Eye Protection:	Use chemical safety goggles (dust proof).
Skin Protection:	For brief contact, few precautions other than clean clothing are needed. Full body clothing impervious to this material should be used during prolonged exposure.
Other:	Safety shower and eyewash stations should be present. Consultation with an industrial hygienist or safety manager for the selection of PPE suitable for working conditions is suggested.
Industrial Hygiene:	Avoid contact with skin and eyes.
Protection Against Fire & Explosion:	NA

Section 7 – Hazards Identification

Emergency Overview:	Oxidizer – Contact with combustibles may cause a fire. This material decomposes and releases oxygen in a fire. The additional oxygen may intensify the fire.
Potential Health Effects:	Irritating to the mucous membrane and eyes. If the product splashes in ones face and eyes, treat the eyes first. Do not dry soiled clothing close to an open flame or heat source. Any

	clothing that has been contaminated with this product should be submerged in water prior to drying.
Inhalation:	High concentrations may cause slight nose and throat irritation with a cough. There is risk of sore throat and nose bleeds if one is exposed to this material for an extended period of time.
Eye Contact:	Severe eye irritation with watering and redness. There is also the risk of serious and/or permanent eye lesions.
Skin Contact:	Irritation may occur if one is exposed to this material for extended periods.
Ingestion:	Irritation of the mouth and throat with nausea and vomiting.

Section 8 – Measures in Case of Accidents and Fire

After Spillage/Leakage/Gas Leakage:	Collect in suitable containers. Wash remainder with copious quantities of water.
Extinguishing Media:	See next.
Suitable:	Large quantities of water or water spray. In case of fire in close proximity, all means of extinguishing are acceptable.
Further Information:	Self contained breathing apparatus or approved gas mask should be worn due to small particle size. Use extinguishing media appropriate for surrounding fire. Apply cooling water to sides of transport or storage vessels that are exposed to flames until the fire is extinguished. Do not approach hot vessels that contain this product.
First Aid:	After contact with skin, wash immediately with plenty of water and soap. In case of contact with eyes, rinse immediately with plenty of water and seek medical attention. Consult an opthalmologist in all cases.

Section 8 – Measures in Case of Accidents and Fire

Eye Contact:	Flush eyes with running water for 15 minutes, while keeping the eyelids wide open. Consult with an ophthalmologist in all cases.
Inhalation:	Remove subject from dusty environment. Consult with a physician in case of respiratory symptoms.

Ingestion:	If the victim is conscious, rinse mouth and admnister fresh water. DO NOT induce vomiting. Consult a physician in all cases.
Skin Contact:	Wash affected skin with running water. Remove and clean clothing. Consult with a physician in case of persistent pain or redness.
Special Precautions:	Evacuate all non-essential personnel. Intervention should only be done by capable personnel that are trained and aware of the hazards associated with this product. When it is safe, unaffected product should be moved to safe area.
Specific Hazards:	Oxidizing substance. Oxygen released on exothermic decomposition may support combustion. Confined spaces and/or containers may be subject to increased pressure. If product comes into contact with flammables, fire or explosion may occur.

Section 9 – Accidental Release Measures

Precautions:	Observe the protection methods cited in Section 3. Avoid materials and products that are incompatible with product. Immediately notify the appropriate authorities in case of reportable discharge (> 100 lbs).
Cleanup Methods:	Collect the product with a suitable means of avoiding dust formation. All receiving equipment should be clean, vented, dry, labeled and made of material that this product is compatible with. Because of the contamination risk, the collected material should be kept in a safe isolated place. Use large quantities of water to clean the impacted area. See Section 12 for disposal methods.

Section 10 – Information on Toxicology

Toxicity Data

Acute Toxicity:	Oral Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Dermal Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Inhalation, LD_{50}, rat, > 5,000 mg/m^3 (powder 35%)
Irritation:	Rabbit (eyes), severe irritant

Sensitization:	No data
Chronic Toxicity:	In vitro, no mutagenic effect (Powder 50%)
Target Organ Effects:	Eyes and respiratory passages.

Section 11 – Information on Ecology

Ecology Data	
	10 mg $Ca(OH)_2$/L: pH = 9.0 100 mg $Ca(OH)_2$/L: pH = 10.6
Acute Exotoxicity:	Fishes, Cyprinus carpio, LC_{50}, 48 hrs, 160 mg/L Crustaceans, Daphnia sp., EC_{50}, 24 hours, 25.6 mg/L (Powder 16%)
Mobility:	Low Solubility and Mobility
Abiotic Degradation:	Water – Slow Hydrolysis. Degradation Products: Calcium Hydroxide Water/soil – complexation/precipitation. Carbonates/sulfates present at environmental concentrations. Degradation products: carbonates/sulfates sparingly soluble
Biotic Degradation:	NA (inorganic compound)
Potential for Bioaccumulation:	NA (ionizable inorganic compound)

Section 11 – Information on Ecology (cont)

Comments:	Observed effects are related to alkaline properties of the product. Hazard for the environment is limited due to the product properties of: • No bioaccumulation • Weak solubility and precipatation as carbonate or sulfate in an aquatic environment. Diluted product is rapidly neutralized at environmental pH.
Further Information:	NA

Section 12 – Disposal Considerations

Waste Disposal Method:	Consult current federal, state and local regulations regarding the proper disposal of this material and its emptied containers.

Section 13 – Shipping/Transport Information

D.O.T Shipping Name:	Oxidizing Solid, N.O.S [A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
UN Number:	1479
Hazard Class:	5.1
Label(s):	5.1 (Oxidizer)
Packaging Group:	II
STCC Number:	4918717

Section 14 – Other Information

HMIS® Rating	Health – 2 Flammability – 0	Reactivity – 1 PPE - Required

HMIS® is a registered trademark of the National Painting and Coating Association.

NFPA® Rating	Health – 2 Flammability – 0	Reactivity – 1 OX

NFPA® is a registered trademark of the National Fire Protection Association.

Reason for Issue: Update toxicological and ecological data

Section 15 – Further Information

The information contained in this document is the best available to the supplier at the time of writing, but is provided without warranty of any kind. Some possible hazards have been determined by analogy to similar classes of material. The items in this document are subject to change and clarification as more information become available.

Attachment C
Proposed Pilot Study of In-Situ Remediation at Vieques, AOC I

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Proposed Pilot Study of In Situ Remediation at Vieques AOC I

PREPARED FOR: Danny Rodriguez/EPA
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PREPARED BY: CH2M HILL, on behalf of the U.S. Navy

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DATE: November 20, 2008

Introduction

The *Final Remedial Investigation Report, Area of Concern (AOC) I, Former Vieques Naval Training Range, Vieques, Puerto Rico* (CH2M HILL, 2008) provided detailed descriptions of site conditions at the former asphalt plant and recommended an additional round of groundwater sampling prior to a Feasibly Study (FS) to evaluate viable remedial alternatives to address the groundwater contamination at AOC I. The additional round of groundwater sampling for the FS was performed in July 2008. The primary objectives of this Technical Memorandum are to summarize the pertinent findings of the July 2008 groundwater sampling event (especially in relation to historical data), and to present a conceptual pilot study plan involving in situ chemical oxidation (ISCO) followed by enhanced in situ bioremediation (EISB) polishing.

The additional round of groundwater sampling in July 2008 was to collect groundwater data reflecting current conditions, and to evaluate concentration trends, especially considering that historical groundwater data indicate concentrations had been low (with respect to regulatory criteria). Groundwater samples collected in July 2008 revealed that all chemicals of concern (COCs) identified in the Remedial Investigation (RI) Report were detected at concentrations below the Maximum Contaminant Levels (MCLs) or potential preliminary remediation goals (PRGs; see "Site Conditions and Assumptions" below) with the exception of benzene and naphthalene. Benzene and naphthalene were detected in only one monitoring well (MW-07) at concentrations (24 and 35 micrograms per liter [µg/L], respectively) above the MCL of 5 µg/L for benzene and the possible PRG of 1.4 µg/L for naphthalene. The preliminary laboratory results (un-validated data) are included in Appendix A. Attenuation trend analysis of these and historic data using the SourceDK Remediation Timeframe Decision Support Tool (Farhat, et al., 2004) estimates it would take 7 years to reach the MCL for benzene and 14 years for naphthalene under a natural attenuation scenario (that is, without treatment), as shown in Appendix B.

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Since the contaminant concentrations have shown a declining trend over the past few years, the COCs in groundwater are limited to a relatively small area adjacent to well MW-07, and the concentrations are relatively low (with respect to regulatory levels), evaluation of various remedial alternatives in a traditional feasibility study may not be the most efficient approach for AOC I. Rather, these conditions make the implementation of a pilot study a more appropriate approach to determine if there is a cost-effective technology that can reduce the already low COC concentrations to acceptable levels in a shorter timeframe than could be achieved through natural processes. The pilot study is designed to take advantage of the existing monitoring well network for the implementation of the pilot study, without the necessity of installing new injection wells and monitoring wells. The close proximity of the monitoring wells in the impacted groundwater area makes it viable to perform the pilot study in a cost-effective way.

The proposed pilot study comprises a two-step systematic approach (ISCO directly followed by EISB polishing). This systematic approach offers a way to increase the intrinsic biodegradation rate and reduce the attenuation time needed to achieve acceptable COC concentrations in groundwater. The remainder of this document provides a conceptual approach to implementing and evaluating a pilot demonstration of enhanced attenuation of the COCs at AOC I.

Site Conditions and Assumptions

The following presents a summary of site geologic and hydrogeologic conditions, results of a baseline human risk assessment, current groundwater conditions, proposed pilot study PRGs, and primary assumptions used in the development of the proposed approach.

Geologic and Hydrogeologic Conditions

The surficial material at the site comprises gravel fill interspersed with silty clay and sand. Beneath the thin veneer of fill, the soil zone at the site is relatively thin (generally 2 to 9 feet thick) and consists of well-graded gravel with sand of the Qa geologic unit. Andesite bedrock lies below the soil, often weathered at its surface to a saprolite. The upper portion of the bedrock is unsaturated. Depth to groundwater typically ranges from 17 to 25 feet below ground surface (bgs), with seasonal fluctuation up to approximately 5 feet. Groundwater at the site migrates through fractures in the bedrock in a north-northwest direction toward the coast. The hydraulic conductivity measured in 2004 and 2006 in the onsite monitoring wells ranged from 0.1 foot per day to 8.6 feet per day. A tidal study conducted on the wells in 2008 indicated groundwater at the site is not tidally influenced. The tidal study results are included in Appendix C.

Summary of Baseline Human Health Risk Assessment (HHRA)

A baseline Human Health Risk Assessment (HHRA) identified six groundwater COCs comprising benzene, bis(2-ethylhexyl)phthalate, 1,2-dichloroethane, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene (CH2M HILL, 2008). No COCs were identified in soil because the potential risks associated with the chemical constituents detected in soil are acceptable. The concentrations of the six groundwater COCs in soil are also lower than the

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concentrations that would likely need to be present to pose a leaching-to-groundwater concern.

Proposed Pilot Study PRGs

PRGs have not been developed for the site-specific COCs. However, for the purposes of considering a potentially suitable remedial technology for the pilot study, the following "Pilot Study PRGs" were considered, based upon the EPA MCLs, or the September 2008 U.S. Environmental Protection Agency (EPA) Regional Screening Levels (RSLs) for constituents without MCLs (Exhibit 1).

EXHIBIT 1
COC Concentrations in Wells MW-04 and MW-07 and Pilot Study PRGs

COCs	July 2008 Maximum Concentrations (µg/L)		Pilot Study PRGs (µg/L)	Source of PRGs
	MW-04	MW-07		
Benzene	5.0	24.0	5.0	MCL
1,2-Dichloroethane	0.5 U	0.5 U	5.0	MCL
1,2-Dichloropropane	0.5 U	0.5 U	5.0	MCL
2-Methylnaphthalene	5.0 U	31.0	150	Hazard Index (HI) of 1 based on the September 2008 EPA Regional Screening Level
Naphthalene	1.1 J	35.0	1.4	Based on the cancer risk of 10^{-5} and the September 2008 EPA Regional Screening Level
Bis(2-ethylhexyl)phthalate	5.0 U	4.2 J	6.0	MCL

Notes:
MCL – Maximum Contaminant Level
µg/L – micrograms per liter
U - Analyzed for, but not detected
J - Estimated results

Summary of Most Recent Groundwater Sampling in July 2008

Groundwater samples collected in 2008 were analyzed for COCs, soluble gases, microbial activity/indicators, and monitored natural attenuation (MNA) parameters. Based on these analyses and those of previous sampling events (2004 and 2006), the concentrations of benzene and naphthalene are gradually declining. However, the concentrations of both benzene and naphthalene still exceed the pilot study PRGs (Exhibit 1). Since the concentrations of other COCs are less than the pilot study PRGs, the concentrations of benzene and naphthalene were used to select the appropriate pilot study technology.

The concentrations of benzene, naphthalene, and selected MNA parameters for the most recent three sampling events within the area of concern (wells MW-04 and MW-07) are summarized in Exhibit 2. Both direct field measurements and sample analysis of natural attenuation parameters since 2002 indicate low oxidation reduction potentials as shown by direct measurement of oxidation-reduction potential (ORP) and by changes in the

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concentration of dissolved oxygen, soluble iron, and soluble manganese. In addition, functional microbial gene analysis of the 2008 groundwater samples revealed no microbial genes for oxidative enzymes (naphthalene dioxygenase and phenol monooxygenase) but moderate levels of those associated with anaerobic catabolism, namely benzylsuccinate synthase. Detailed discussion of the functional gene analyses, microbial community structure, and microbial physiological status is reported in Appendix D. Taken in their entirety, these data suggest active biological attenuation processes are responsible in part, for the attenuation of benzene and naphthalene. However, under the present anaerobic conditions, the biodegradation kinetics of benzene and naphthalene are projected to extend attainment of the PRGs 7 to 14 years, respectively (Appendix B). Aerobic conditions produce the highest biodegradation rates for both benzene and naphthalene and offer the best opportunity to enhance attenuation processes and achieve the pilot study PRG goals.

EXHIBIT 2
Summary of Groundwater COC Concentrations, selected MNA Parameters, and Proposed Goals

Parameter	Units	MW-04			MW-07			Goal
		09/23/04	01/10/06	07/23/08	09/24/04	01/10/06	07/22/08	
Dissolved Oxygen	mg/L	NA	NA	1.3	NA	NA	1.80	> 2.0
ORP	mV	NA	-41.1	-38.5	NA	-59.5	1.6	>300
pH	units	NA	6.81	6.96	NA	6.73	6.56	6.5-7.5
Soluble Iron	mg/L	0.017J	0.117	0.0532 J	0.188 J	1.47	1.03	<0.01
Soluble Manganese	mg/L	1.93	1.96	1.67	1.28	1.76	1.68	<0.01
Benzene	µg/L	33.7	4.6	5	59.3	28	24	<5
Naphthalene	µg/L	46.2	50.5	1.1 J	81.4	96	35	<1.4

Notes:
mg/L – milligrams per liter
mV – millivolts
µg/L – micrograms per liter
J –Estimated results
NA – Not available

Pilot Study Approach and Rationale

A two-step approach is proposed: 1) direct chemical destruction of COCs by ISCO and adjustment of the aquifer ORP into the positive and aerobic range (>+300 millivolts [mV]), followed by 2) sustained, time-release delivery of oxygen to support aerobic EISB of residual COC contamination.

Because the site is unoccupied, there is no site security, and there is potential for equipment vandalism/theft, subsurface remedial installations and injections with minimal or no operation and maintenance (O&M) requirements are preferred over aboveground systems such as air sparging/soil vapor extraction systems that require frequent O&M. In addition, lack of access to utilities may limit installation and operation of such systems.

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In Situ Chemical Oxidation (ISCO)

Several chemical oxidants are available for ISCO treatment. Sodium persulfate is recommended as the chemical oxidant because it is:

- Strong enough to chemically oxidize benzene and naphthalene
- Persistent enough to exploit redistribution by natural diffusion and advective mixing
- Completely soluble (avoids formation plugging)
- Degrades to naturally occurring sulfate salts
- Strong enough to condition the aquifer to the positive ORP required for subsequent aerobic biodegradation

The area of COC groundwater contamination is approximately 25 feet long by 25 feet wide. Due to the relatively tight formation, persulfate will be injected via four existing monitoring wells, located in the former source area (MW-07), up-gradient (well MW-02) and side gradient (wells MW-04 and MW-03) to the primary area of concern (around MW-07), as shown in Exhibit 3. Persulfate solution activated with chelated iron will be injected under pressure into the saturated zone. Even though the anaerobic geochemistry provides about 1 to 2 mg/L soluble iron, additional chelated iron catalyst will be required for complete activation of the persulfate oxidant. The immediate 8- to 10-ft radius of influence expected during injection is expected to double due to natural groundwater flow and water table flux during the 90-day incubation period following oxidant injection. In addition to lateral dispersion, injection will create mounding of the water table, thereby treating some of the capillary fringe and smear zone. During the incubation period, activated persulfate will oxidized organic compounds and adjust the aquifer to an aerobic redox potential. During this process persulfate will degrade to sulfate, an innocuous salt present in the aquifer. Ninety (90) days (3 months) after the ISCO injection, direct field measurements and groundwater samples will be collected from wells MW-02, MW-03, MW-04, MW-05, and MW-07 for analysis of sulfate and for the parameters listed in Exhibit 2.

Enhanced In Situ Bioremediation (EISB)

Following the 3-month groundwater sample-collection event at the end of the ISCO incubation period, oxygen-releasing socks will be installed into wells MW-02, MW-03, MW-04, MW-05, and MW-07 to provide an ongoing source of molecular oxygen to enhance in situ aerobic biodegradation within the formation. The socks support aerobic biodegradation by providing oxygen for approximately 9 months. Natural groundwater flow and water table fluctuations associated with seasonal precipitation are anticipated to provide the advective mixing needed to distribute oxygen through out the treatment zone. After 9 months of incubation, the socks will be removed, the monitoring wells will be allowed to equilibrate with the formation for 3 months and a final set of groundwater samples will be collected and analyzed for sulfate and for the parameters listed in Exhibit 2.

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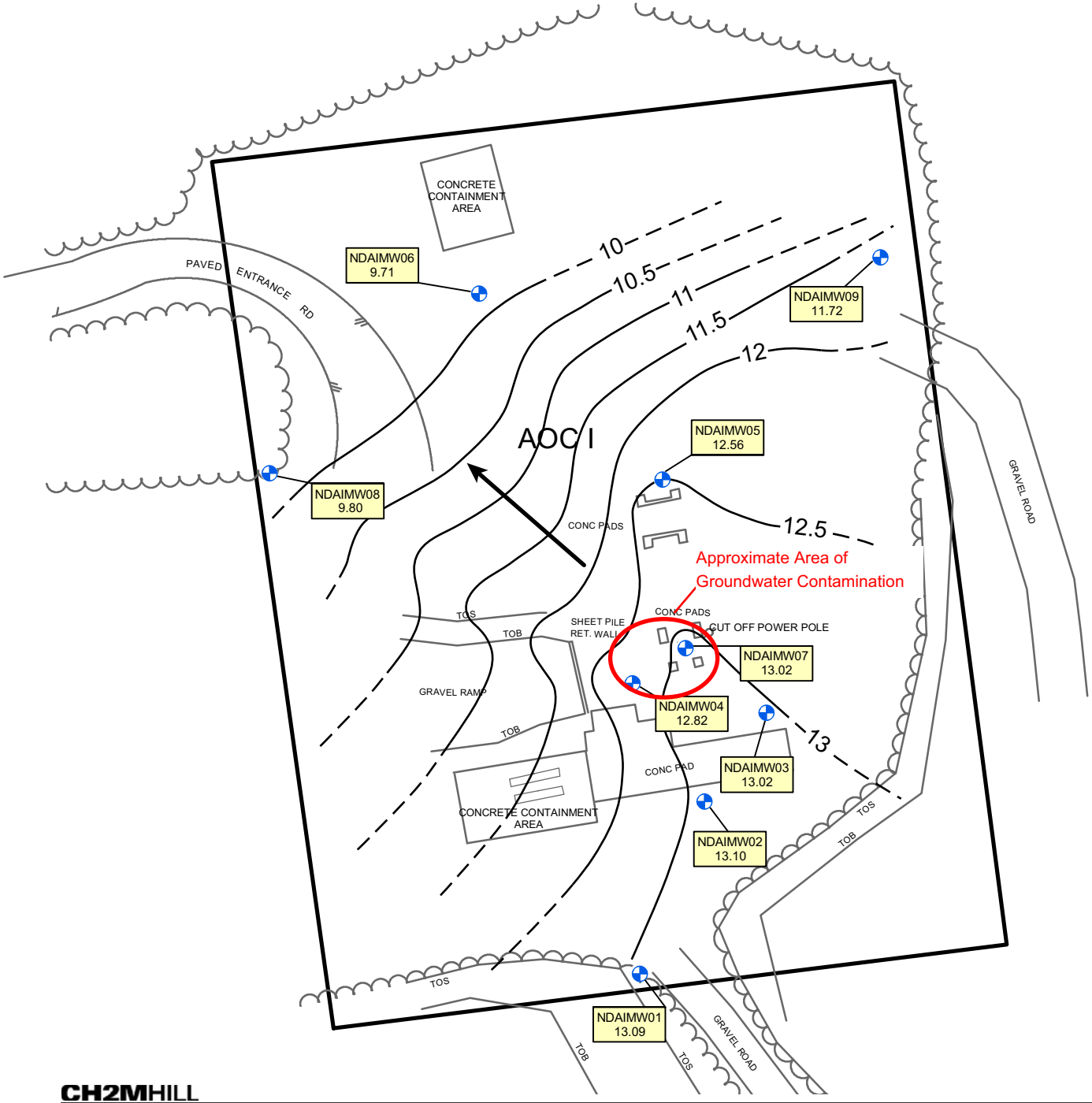

LEGEND

- AOC I Area from EBS 2000
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Location
- Estimated Groundwater Contours, dashed where inferred (0.5' Intervals)
- Estimated Direction of Groundwater Flow

Groundwater elevations in FT MSL.
Water Level readings taken on March 17, 2006

N

0 25 50 Feet

Exhibit 3
Estimated Potentiometric Surface
AOC I Remedial Investigation Report
Vieques, Puerto Rico

CH2MHILL

ES072007002TPA 180357.RI.RI.AI

Expected Results

Activated persulfate will oxidize benzene and naphthalene on contact and will adjust the aquifer ORP into the positive range to support aerobic biodegradation. The extent of COC destruction and aquifer adjustment will be evaluated by field measurements of dissolved oxygen, ORP, and by sample analysis for COCs, soluble iron, and soluble manganese 3 months after the ISCO application. ISCO is expected to set the stage for sustained, aerobic in situ bioremediation by reducing the concentration of COCs and eliminating much of the existing chemical oxygen demand. The oxygen-releasing socks will prolong the aerobic environment for an additional 9 months while groundwater flow and water table flux provide natural redistribution of oxygen within the formation.

Schedule

Exhibit 4 presents the proposed schedule showing ISCO treatment, EISB treatment, monitoring, sample collection, and reporting. This schedule assumes a start date after agency concurrence on the pilot study approach and assumes the EISB oxygen-delivery sock installations would occur 3 months after the initial ISCO injection, immediately after sample collection. Following ISCO injection and 3 months of incubation, performance data will be collected, analyzed, and evaluated to produce an interim ISCO status report. Approximately 9 months after EISB oxygen-sock installation, the socks will be removed, the monitoring wells will be allowed to equilibrate with the formation for 3 months and a final set of samples will be collected. A draft pilot study report will be delivered 60 days after the final round of sampling data are loaded into the Vieques database. The pilot study report will include recommendations of the path forward (e.g., FS, additional pilot study, no further action, etc.).

EXHIBIT 4
Proposed Schedule for ISCO Followed by EISB

	Months																		
Tasks	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Chemical Oxidant Injection (ISCO) and Incubation	x																		
Field Monitoring				x											x				
Sample Collection and Analysis				x											x				
Application/Incubation of Oxygen-Releasing Socks				x															
Remove Oxygen Socks for Well Equilibration													x						
ISCO Status Progress Report							x												
Draft Pilot Study Report																			x

Notes:
X indicates month of field deployment event or report delivery
Shading indicates anticipated duration of treatment

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References

CH2M HILL. 2008. *Final Remedial Investigation Report, Area of Concern (AOC) I, Former Naval Ammunition Support Detachment Vieques, Puerto Rico*. June.

Farhat, S. K., P.C. de Blanc, C.J. Newell, J. R. Gonzales and J. Perez. 2004. SourceDK Remediation Timeframe Decision Support System – Users Manual Version 1.0. Air Force Center for Environmental Excellence Technology Transfer, Brooks AFB, Texas.

Appendices

Appendix A Additional Groundwater Sampling Data in July 2008

Appendix B SourceDK Analysis of Monitoring wells MW-04 and MW-07

Appendix C Summary of Tidal Study Results

Appendix D Biological Data AOC I July 2008

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Appendix A
Additional Groundwater Sampling Data in July 2008

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CTO-010
Vieques - West AOC I
Validated Groundwater Detected Analytical Results
July 2008

Sample ID	VWAI-MW01-08C	VWAI-MW02-08C	VWAI-MW03-08C	VWAI-MW04-08C		VWAI-MW05-08C		VWAI-MW05P-08C		VWAI-MW06-08C	VWAI-MW07-08C		VWAI-MW08-08C	VWAI-MW09-08C
Sample Date	7/23/08	7/24/08	7/24/08	7/23/08		7/21/08		7/21/08		7/27/08	7/22/08		7/20/08	7/22/08
Chemical Name														
Volatile Organic Compounds (UG/L)														
1,2-DIBROMO-3-CHLOROPROPANE	0.05 U	0.05 U	0.05 U	0.05 U	NA	1.1	NA	0.05 U	NA	0.05 U	0.05 U	NA	0.05 U	0.05 U
BENZENE	0.5 U	0.5 U	0.14 J	5	NA	0.5 U	NA	0.5 U	NA	0.5 U	24	NA	0.5 U	0.5 U
CARBON DISULFIDE	0.5 U	0.5 U	0.5 U	0.5 U	NA	0.11 J	NA	0.12 J	NA	0.5 U	2.5 UJ	NA	0.5 U	0.5 U
CHLOROFORM	0.5 U	0.5 U	0.5 U	0.16 J	NA	0.5 U	NA	0.5 U	NA	0.5 U	2.5 U	NA	0.5 U	0.5 U
CYCLOHEXANE	0.5 U	0.5 U	2.3	3.6	NA	0.5 U	NA	0.5 U	NA	0.5 U	48	NA	0.5 U	0.5 U
ETHYLBENZENE	0.5 U	0.5 U	0.5 U	0.12 J	NA	0.5 U	NA	0.5 U	NA	0.5 U	1.3 J	NA	0.5 U	0.5 U
ISOPROPYLBENZENE	0.5 U	0.5 U	0.69	2.9	NA	1.5	NA	1.4	NA	0.5 U	26	NA	0.5 U	0.5 U
m- and p-Xylene	0.48 J	0.5 U	0.62	0.14 J	NA	0.5 U	NA	0.5 U	NA	0.5 U	2.6	NA	0.5 U	0.56
METHYLCYCLOHEXANE	0.5 U	0.5 U	0.83	0.55	NA	0.58	NA	0.55	NA	0.5 U	21	NA	0.5 U	0.5 U
O-XYLENE	0.16 J	0.5 U	0.25 J	0.5 U	NA	0.5 U	NA	0.5 U	NA	0.5 U	2.5 U	NA	0.5 U	0.18 J
TOLUENE	0.5 U	0.5 U	0.5 U	0.1 J	NA	0.5 U	NA	0.5 U	NA	0.5 U	0.98 J	NA	0.5 U	0.5 U
TRICHLOROETHENE	0.5 U	0.5 U	0.5 U	0.5 U	NA	0.5 U	NA	0.5 U	NA	0.19 J	2.5 U	NA	0.5 U	0.5 U
Semivolatile Organic Compounds (UG/L)														
2-METHYLNAPHTHALENE	0.093 U	0.1 U	1.3	0.47	NA	7.5	NA	5.4	NA	0.1 U	31	NA	0.1 UJ	0.095 U
ACENAPHTHENE	0.093 U	0.1 U	0.56 J	0.77 J	NA	1.1	NA	0.76	NA	0.1 U	1.1 J	NA	0.1 UJ	0.095 U
ANTHRACENE	0.093 U	0.1 U	0.14 J	0.14	NA	0.12 J	NA	0.092 J	NA	0.1 U	0.21 J	NA	0.1 UJ	0.095 U
BIS(2-ETHYLHEXYL)PHTHALATE	4.7 U	5 U	5 U	5 U	NA	5 U	NA	5 U	NA	5.1 U	4.2 J	NA	5 U	4.8 U
FLUORANTHENE	0.093 U	0.1 U	0.1 UJ	0.1 U	NA	0.1 UJ	NA	0.1 UJ	NA	0.1 U	0.077 J	NA	0.1 UJ	0.095 U
FLUORENE	0.093 U	0.1 U	1.5	1.8	NA	1.6	NA	1.2	NA	0.1 U	4.5 J	NA	0.1 UJ	0.095 U
NAPHTHALENE	0.093 U	0.1 U	0.71 J	1.1	NA	0.33 J	NA	0.26 J	NA	0.1 U	35	NA	0.1 UJ	0.095 U
PHENANTHRENE	0.093 U	0.1 U	0.31 J	0.1 U	NA	2.5	NA	1.9	NA	0.1 U	3.5	NA	0.075 J	0.095 U
PYRENE	0.093 U	0.1 U	0.1 J	0.18	NA	0.1 UJ	NA	0.1 UJ	NA	0.1 U	0.085 J	NA	0.1 UJ	0.095 U
Total Metals (UG/L)														
ALUMINUM	200 U	200 U	233	200 U	NA	200 U	NA	200 U	NA	200 U	200 U	NA	200 U	393
ANTIMONY	2 U	0.37 J	0.055 J	0.26 J	NA	0.28 J	NA	0.25 R	NA	1.3 J	0.29 J	NA	0.32 J	0.075 J
ARSENIC	1 U	0.65 J	3.3	5.1	NA	9.9	NA	9.9	NA	1.4 J	4.8	NA	1.2	0.83 J
BARIUM	1.1 J	41	83.3	86.3	NA	87.3	NA	84.7	NA	16.3 J	64.7	NA	83.1	43.7
CALCIUM	87,900	89,900	78,000	57,700	NA	55,100	NA	54,200	NA	43,900	64,600	NA	63,400	54,600
CHROMIUM	0.39 J	1.7 J	7.4	0.3 J	NA	3.4	NA	3.4	NA	2 U	1.6 J	NA	0.53 J	0.79 J
COBALT	1 U	0.78 J	0.6 J	0.65 J	NA	0.84 J	NA	0.8 J	NA	0.21 J	0.96 J	NA	0.49 J	0.92 J
COPPER	2 U	2.3	2.6	2.6	NA	3.4	NA	3.6	NA	5.2 J	4.4	NA	3.6	5
IRON	100 U	100 U	644	139	NA	127	NA	132	NA	100 U	1,080	NA	100 U	313
LEAD	0.12 J	0.057 J	1 U	0.076 J	NA	0.28 R	NA	0.057 J	NA	0.07 J	0.58 J	NA	0.21 J	0.23 J
MAGNESIUM	53,200	59,500	57,200	48,400	NA	42,000	NA	41,200	NA	21,200	54,000	NA	35,400	48,800
MANGANESE	2.2	1,200	1,700	1,830	NA	1,260	NA	1,270	NA	8.9 J	1,680	NA	171	263
NICKEL	2 J	6.3	15.7	2	NA	3.5	NA	3.6	NA	3 J	3.7	NA	2.8	6.2
SELENIUM	5 U	0.95 J	0.81 J	1.2 J	NA	0.81 J	NA	0.95 J	NA	4.3 J	0.93 J	NA	2.5 J	1.2 J
SODIUM	116,000	76,300	94,600	150,000	NA	231,000	NA	228,000	NA	378,000	168,000	NA	205,000	273,000
VANADIUM	5 U	29.3	0.64 J	1.6 J	NA	0.99 J	NA	0.98 J	NA	42.8 J	1.2 J	NA	26.2	28.5
ZINC	4.2	2.2	2.7	3.7	NA	4.1 J	NA	3.2 R	NA	2.1 J	7	NA	2.7 J	1.8 R
Dissolved Metals (UG/L)														
ANTIMONY	0.21 J	0.32 J	0.059 J	0.29 J	NA	0.38 J	NA	0.41 R	NA	1.2 J	0.19 J	NA	0.37 J	0.079 J
ARSENIC	0.97 J	0.63 J	3.1	5.5	NA	10.3	NA	11.6	NA	1.6	5.3	NA	1.5	0.88 J
BARIUM	18.8	38.3	76.7	79.5	NA	85.8	NA	92.3	NA	17	64.2	NA	87.8	37.7
CALCIUM	86,200	91,700	79,500	59,200	NA	55,500	NA	55,800	NA	43,800	67,200	NA	65,600	54,600
COBALT	0.17 J	0.7 J	0.46 J	0.59 J	NA	0.75 J	NA	0.91 J	NA	0.27 J	0.99 J	NA	0.44 J	0.8 J
COPPER	2	1.9 J	0.99 J	1.8 J	NA	2.1	NA	3	NA	4.6	2.1	NA	3.3	3.3
IRON	100 U	100 U	321	100 U	NA	100 U	NA	100 U	NA	100 U	1,030	NA	100 U	100 U
LEAD	0.12 J	0.058 J	0.064 J	1 U	NA	0.088 J	NA	0.1 J	NA	0.15 J	0.16 J	NA	0.11 J	0.18 J
MAGNESIUM	50,500	60,700	58,600	49,800	NA	42,400	NA	42,500	NA	21,300	56,300	NA	36,400	49,200
NICKEL	3.7	5	12.3	1.8	NA	2.6	NA	3.1	NA	3	3.7	NA	2.7	5.4
SELENIUM	3.5 J	0.94 J	0.84 J	1.1 J	NA	0.8 J	NA	0.91 J	NA	6.1	0.95 J	NA	2.7 J	1 J
SODIUM	108,000	78,400	96,400	154,000	NA	231,000	NA	232,000	NA	379,000	172,000	NA	211,000	271,000
VANADIUM	42.2	26.9	5 U	5 U	NA	5 U	NA	5 U	NA	46.5	5 U	NA	32.8	26.5
ZINC	3.1	1.8 J	2	2.5	NA	5.5 J	NA	5.4 R	NA	5.3	5.3	NA	5 J	3.2 R
Wet Chemistry (MG/L)														

CTO-010
Vieques - West AOC I
Validated Groundwater Detected Analytical Results
July 2008

Sample ID	VWAI-MW01-08C	VWAI-MW02-08C	VWAI-MW03-08C	VWAI-MW04-08C		VWAI-MW05-08C		VWAI-MW05P-08C		VWAI-MW06-08C	VWAI-MW07-08C		VWAI-MW08-08C	VWAI-MW09-08C
Sample Date	7/23/08	7/24/08	7/24/08	7/23/08		7/21/08		7/21/08		7/27/08	7/22/08		7/20/08	7/22/08
Chemical Name														
CHLORIDE	NA	NA	NA	47	NA	32.8	NA	36.8	NA	NA	31.7	NA	NA	NA
ETHANE	NA	NA	NA	0.4 J	0.2 JD	2 U	8 U	2 U	8 U	NA	0.7 J	0.3 JD	NA	NA
SULFATE	NA	NA	NA	10.8	NA	5 U	NA	5 U	NA	NA	5 U	NA	NA	NA
TOC	NA	NA	NA	2.31 B	NA	6.27	NA	6.19	NA	NA	4.49 B	NA	NA	NA
TOTAL ALKALINITY	NA	NA	NA	632	NA	812	NA	822	NA	NA	786	NA	NA	NA
Total Petroleum Hydrocarbons (MG/L)														
TPH-diesel range	0.5 U	0.5 U	0.5 U	0.5 U	NA	0.57	NA	0.59	NA	0.56 U	1.2	NA	0.5 U	0.5 U
TPH-gas range	0.5 U	0.5 U	0.5 U	0.67	NA	0.5 U	NA	0.5 U	NA	0.5 U	0.84	NA	0.5 U	0.5 U
Biomass (CELLS/ML)														
Cells	NA	NA	NA	7,960	NA	NA	NA	NA	NA	NA	45,100	NA	NA	NA
Community Structure (PCT)														
Actinomycetes	NA	NA	NA	5.56	NA	NA	NA	NA	NA	NA	9.54	NA	NA	NA
Anaerobic metal reducers	NA	NA	NA	2.84	NA	NA	NA	NA	NA	NA	4.27	NA	NA	NA
Eukaryotes	NA	NA	NA	1.87	NA	NA	NA	NA	NA	NA	0.99	NA	NA	NA
Firmicutes	NA	NA	NA	18.3	NA	NA	NA	NA	NA	NA	17.6	NA	NA	NA
General Nsats	NA	NA	NA	32.9	NA	NA	NA	NA	NA	NA	30.0	NA	NA	NA
Proteobacteria	NA	NA	NA	38.5	NA	NA	NA	NA	NA	NA	37.5	NA	NA	NA
Dechlorinating Bacteria (GC/ML)														
Dehalobacter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1,020	NA	NA	NA
Benzyl Succinante Synthase	NA	NA	NA	3.83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Physiological Status (RATIO)														
Decreased Permeability	NA	NA	NA	0 U	NA	NA	NA	NA	NA	NA	0.338	NA	NA	NA
Slowed Growth	NA	NA	NA	0.593	NA	NA	NA	NA	NA	NA	1.12	NA	NA	NA

Notes:

B - Analyte not detected above the level reported in blanks
J - Analyte present. Value may or may not be accurate or precise
NA - Not analyzed
R - Unreliable Result
U - The material was analyed for, but not detected
UJ - Analyte not detected, quantitation limit may be inaccurate
CELLS/ML - Cells per milliliter
GC/ML - Gene copies per milliliter
MG/L - Milligrams per liter
PCT - Percent
RATIO - ratio
UG/L - Micrograms per liter
Shading indicates detection

Appendix B
SourceDK Analysis of Monitoring Wells MW-04 and MW-07

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SourceDK TIER 1 Empirical Data

Remediation Timeframe Decision Support System

Air Force Center for Environmental Excellence *Version 1.0*

Site Location and I.D.: AOC I (MW-07, MW-04, mean)

Constituent of Interest: Naphthalene

Data Input Instructions:

10.80 → *Enter value directly.*

10.80 → *Value calculated by model. (Don't enter any data).*

1. ENTER CONSTITUENT NAME AND HISTORICAL DATA

Concentration ug/L

	Date (mm/dd/yy)	Constituent A	Constituent B	Constituent C	Constituent D
		Naphthalene07	***Naphthalene04***	***naphth mean***	
1	*2004-09-24*	*81.4*	*46.2*	*63.8*	
2	*2006-01-10*	*96*	*50.5*	*73.25*	
3	*2008-07-22*	*35*	*1.1*	*18.05*	
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

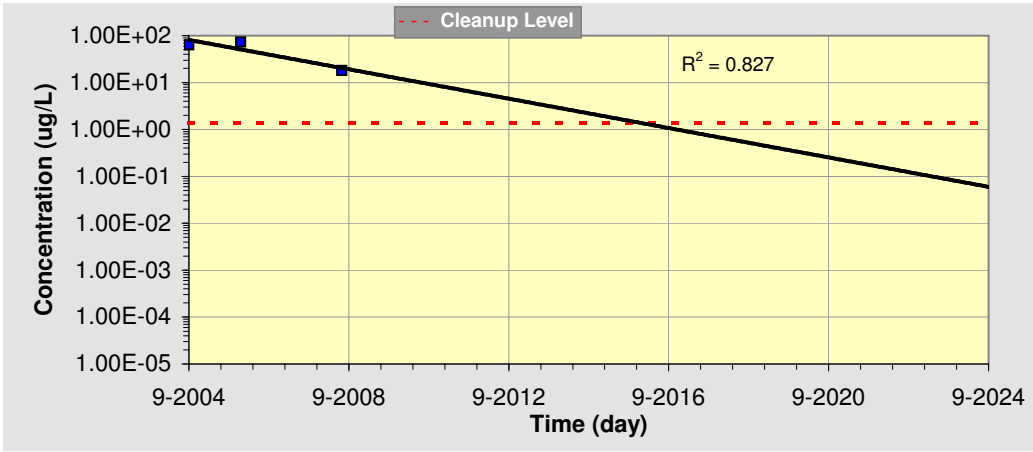
Print Historical Data

2. WHICH CONSTITUENT TO PLOT?

What is the cleanup level?

○	Naphthalene07	1.4 (ug/L)
○	Naphthalene04	1.4 (ug/L)
◉	**naphth mean**	1.4 (ug/L)
○	Constituent D	(ug/L)

3. OUTPUT GRAPH



Number of Years Over Which to Plot Graph 20 *(yr)* Update Graph

4. RESULTS

Predicted Date to Achieve Cleanup: **2015**

Confidence Interval on Predicted Cleanup Date:
(at least 3 data points needed to calculate confidence intervals)

◉ 90 % Confidence Interval
○ 95 % Confidence Interval

2005 (Lower Limit on Confidence Interval) to **Can't Calc (+ve Trend)** (Upper Limit on Confidence Interval)

Source Decay Rate Constant (1/year): **3.61E-01**
(positive numbers represent shrinking plumes while negative numbers represent expanding plumes)

Return To Main Screen | ***New Site/Clear Screen*** | ***Paste Example Data Set*** | ***HELP***

SourceDK TIER 1 Empirical Data

Remediation Timeframe Decision Support System

Air Force Center for Environmental Excellence *Version 1.0*

Site Location and I.D.: AOC I (MW-07, MW-04, mean)

Constituent of Interest: Naphthalene

Data Input Instructions:

10.80 → *Enter value directly.*

10.80 → *Value calculated by model. (Don't enter any data).*

1. ENTER CONSTITUENT NAME AND HISTORICAL DATA

Concentration ug/L

	Date (mm/dd/yy)	Constituent A	Constituent B	Constituent C	Constituent D
		Naphthalene07	***Naphthalene04***	***naphth mean***	
1	*2004-09-24*	*81.4*	*46.2*	*63.8*	
2	*2006-01-10*	*96*	*50.5*	*73.25*	
3	*2008-07-22*	*35*	*1.1*	*18.05*	
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Print Historical Data

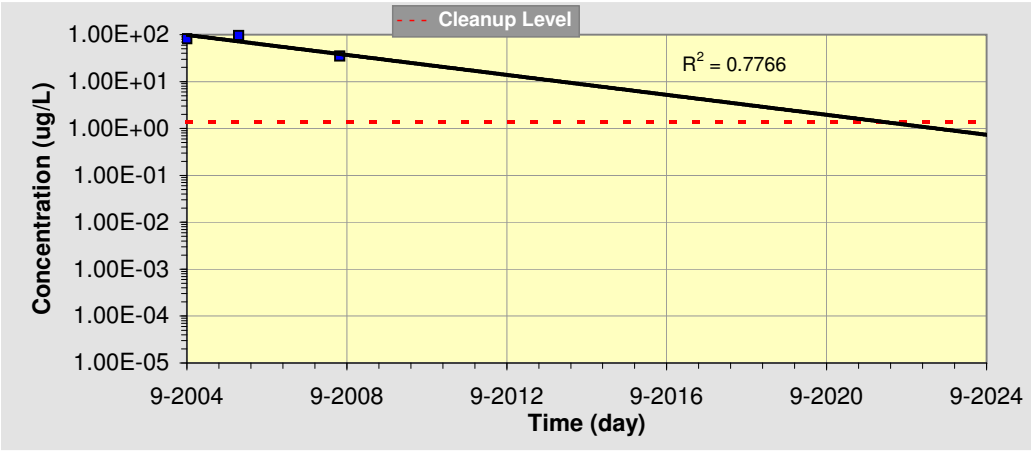
2. WHICH CONSTITUENT TO PLOT?

What is the cleanup level?

◉	**Naphthalene07**	1.4 (ug/L)
○	Naphthalene04	1.4 (ug/L)
○	naphth mean	1.4 (ug/L)
○	Constituent D	(ug/L)

3. OUTPUT GRAPH

DISSOLVED NAPHTHALENE07 CONCENTRATION (ug/L)



Number of Years Over Which to Plot Graph 20 *(yr)* Update Graph

4. RESULTS

Predicted Date to Achieve Cleanup: **2022**

Confidence Interval on Predicted Cleanup Date:
(at least 3 data points needed to calculate confidence intervals)

◉ 90 % Confidence Interval
○ 95 % Confidence Interval

2006 (Lower Limit on Confidence Interval) to **Can't Calc (+ve Trend)** (Upper Limit on Confidence Interval)

Source Decay Rate Constant (1/year): **2.45E-01**
(positive numbers represent shrinking plumes while negative numbers represent expanding plumes)

Return To Main Screen | ***New Site/Clear Screen*** | ***Paste Example Data Set*** | ***HELP***

SourceDK TIER 1 Empirical Data

Remediation Timeframe Decision Support System

Air Force Center for Environmental Excellence *Version 1.0*

Site Location and I.D.: AOC I (MW-07, MW-04, mean)

Constituent of Interest: Benzene

Data Input Instructions:

10.80 → *Enter value directly.*

10.80 → *Value calculated by model. (Don't enter any data).*

1. ENTER CONSTITUENT NAME AND HISTORICAL DATA

Concentration ug/L

	Date (mm/dd/yy)	Constituent A	Constituent B	Constituent C	Constituent D
		Benzene07	***Benzene04***	***Benzene mean***	
1	*2004-09-24*	*59.3*	*33.7*	*46.5*	
2	*2006-01-10*	*28*	*4.6*	*16.3*	
3	*2008-07-22*	*24*	*5*	*14.5*	
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Print Historical Data

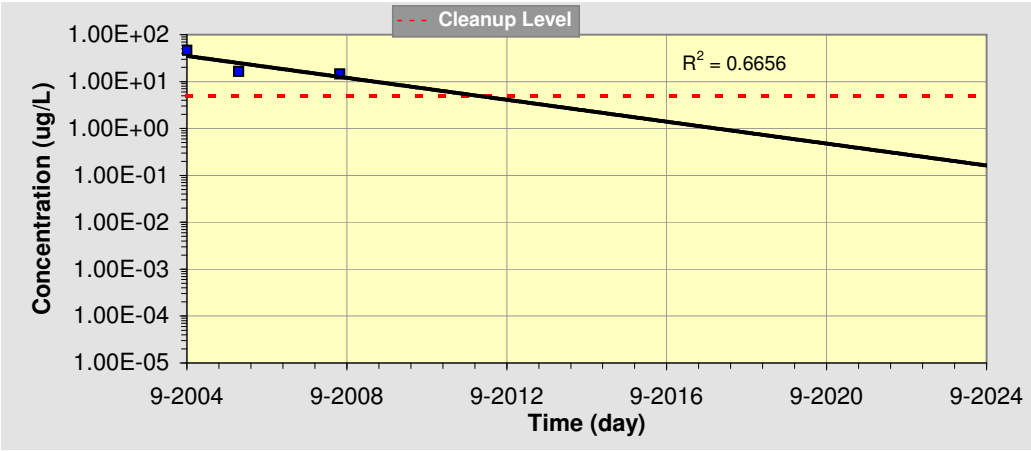
2. WHICH CONSTITUENT TO PLOT?

What is the cleanup level?

○	Benzene07	5 (ug/L)
○	Benzene04	5 (ug/L)
◉	**Benzene mean**	5 (ug/L)
○	Constituent D	(ug/L)

3. OUTPUT GRAPH

DISSOLVED BENZENE MEAN CONCENTRATION (ug/L)



Number of Years Over Which to Plot Graph 20 *(yr)* Update Graph

4. RESULTS

Predicted Date to Achieve Cleanup: **2011**

Confidence Interval on Predicted Cleanup Date:
(at least 3 data points needed to calculate confidence intervals)

◉ 90 % Confidence Interval
○ 95 % Confidence Interval

2004 (Lower Limit on Confidence Interval) to **Can't Calc (+ve Trend)** (Upper Limit on Confidence Interval)

Source Decay Rate Constant (1/year): **2.69E-01**
(positive numbers represent shrinking plumes while negative numbers represent expanding plumes)

Return To Main Screen | ***New Site/Clear Screen*** | ***Paste Example Data Set*** | ***HELP***

SourceDK TIER 1 Empirical Data

Remediation Timeframe Decision Support System

Air Force Center for Environmental Excellence *Version 1.0*

Site Location and I.D.: AOC I (MW-07, MW-04, mean)

Constituent of Interest: Benzene

Data Input Instructions:

10.80 → *Enter value directly.*

10.80 → *Value calculated by model. (Don't enter any data).*

1. ENTER CONSTITUENT NAME AND HISTORICAL DATA

Concentration ug/L

	Date (mm/dd/yy)	Constituent A	Constituent B	Constituent C	Constituent D
		Benzene07	***Benzene04***	***Benzene mean***	
1	*2004-09-24*	*59.3*	*33.7*	*46.5*	
2	*2006-01-10*	*28*	*4.6*	*16.3*	
3	*2008-07-22*	*24*	*5*	*14.5*	
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Print Historical Data

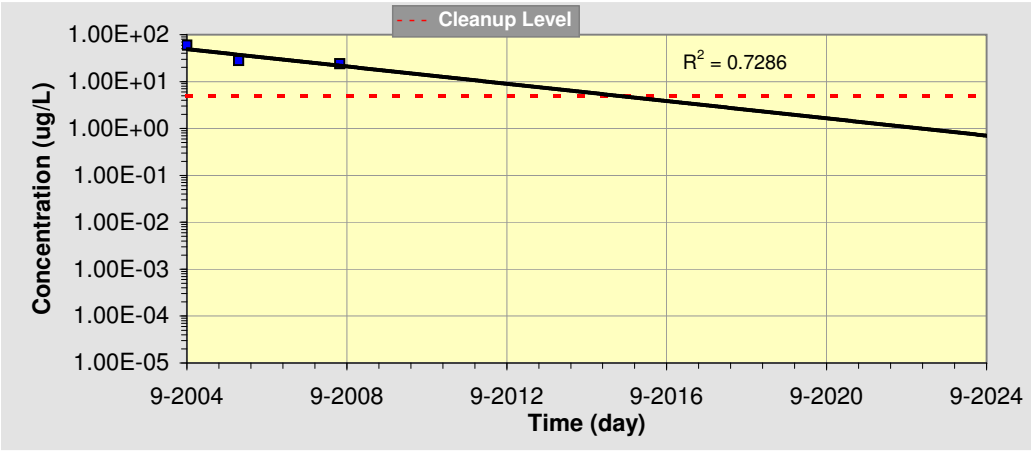
2. WHICH CONSTITUENT TO PLOT?

What is the cleanup level?

- (●) **Benzene07** 5 (ug/L)
- ( ) Benzene04 5 (ug/L)
- ( ) Benzene mean 5 (ug/L)
- ( ) Constituent D (ug/L)

3. OUTPUT GRAPH

DISSOLVED BENZENE07 CONCENTRATION (ug/L)



Number of Years Over Which to Plot Graph 20 *(yr)* Update Graph

4. RESULTS

Predicted Date to Achieve Cleanup: **2015**

Confidence Interval on Predicted Cleanup Date:
(at least 3 data points needed to calculate confidence intervals)

(●) 90 % Confidence Interval
( ) 95 % Confidence Interval

2005 (Lower Limit on Confidence Interval) to **Can't Calc (+ve Trend)** (Upper Limit on Confidence Interval)

Source Decay Rate Constant (1/year): **2.12E-01**
(positive numbers represent shrinking plumes while negative numbers represent expanding plumes)

Return To Main Screen | ***New Site/Clear Screen*** | ***Paste Example Data Set*** | ***HELP***

Appendix C
Summary of Tidal Study Results

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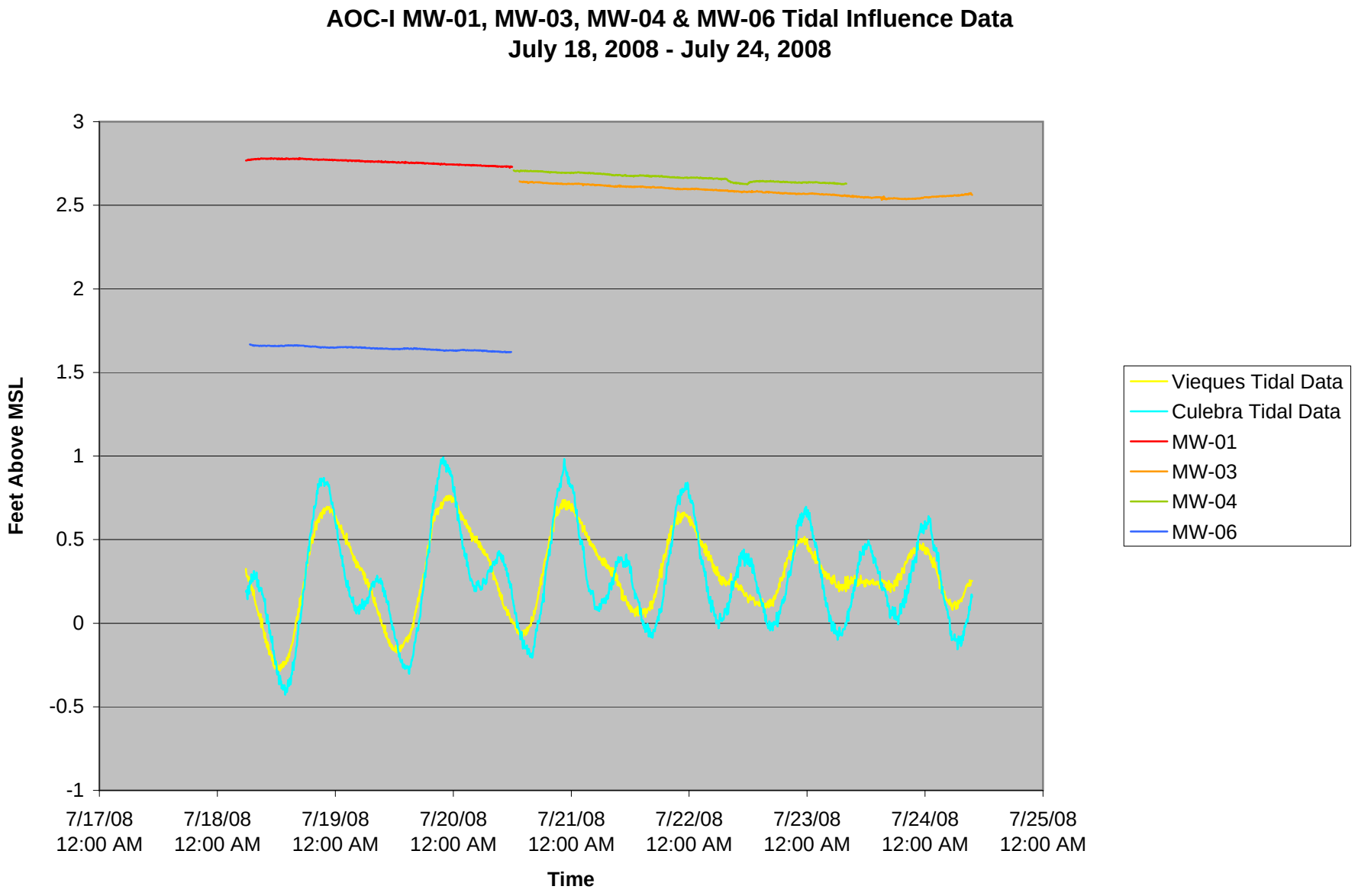
AOC-I MW-01, MW-03, MW-04 & MW-06 Tidal Influence Data
July 18, 2008 - July 24, 2008
Feet Above MSL
3
2.5
2
1.5
1
0.5
0
-0.5
-1
7/17/08 12:00 AM
7/18/08 12:00 AM
7/19/08 12:00 AM
7/20/08 12:00 AM
7/21/08 12:00 AM
7/22/08 12:00 AM
7/23/08 12:00 AM
7/24/08 12:00 AM
7/25/08 12:00 AM
Time
Vieques Tidal Data
Culebra Tidal Data
MW-01
MW-03
MW-04
MW-06

Appendix D
Biological Data AOC I July 2008

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Interpretation of Biological Data and Indicators from Groundwater from AOC I, Vieques, Puerto Rico

PREPARED FOR:	Danny Rodriguez/EPA Wilmarie Rivera/PREQB Richard Henry/USFWS
PREPARED BY:	CH2M HILL, on behalf of the U.S. Navy
COPIES:	Kevin Cloe/NAVFAC Madeline Rivera/NAVFAC Dan Hood/NAVFAC Chris Penny/NAVFAC
DATE:	November 20, 2008
PROJECT NUMBER:	180357.FS.DR.AI

Introduction

As part of the remedial investigation for the Area of Concern I (AOC I), groundwater samples collected from two monitoring wells (MW-04 and MW-07) on July 22-23, 2008 were analyzed for microbial phospholipid fatty acids (PLFA) and deoxyribonucleic acid (DNA) by quantitative polymerase chain reaction (qPCR) to gain insight into the biomass, biological community structure, physiological status, and the presence of selected enzymes and microbes. This technical memorandum presents a summary and interpretation of the biological data with respect to the potential for biologically supported contaminant degradation (i.e., biodegradation). The analytical results associated with this memorandum are presented in Appendix A of the *Technical Memorandum - Proposed Pilot Demonstration of In Situ Remediation at Vieques AOC I* (CH2M HILL, November 2008).

Phospholipid Fatty Acids (PLFA) Analysis

The PLFA are an essential component of intact cell membranes of living cells. The composition of the cell membranes of various microbial communities is so unique that their concentrations and distribution is indicative of not only the total biomass but also the relative population density of major microbial groups in the community. In addition to determining the total biomass and the community structure, PLFA analyses can also provide insight into the physiological status of the Gram-negative bacteria, generally considered to be the dominant biodegradation population.

Biomass

Because PLFA analysis measures essential components of the actual microbial cell, the analysis provides a more accurate measurement of total biomass than traditional enumeration methods that require microbial growth for counting. Consequently, population

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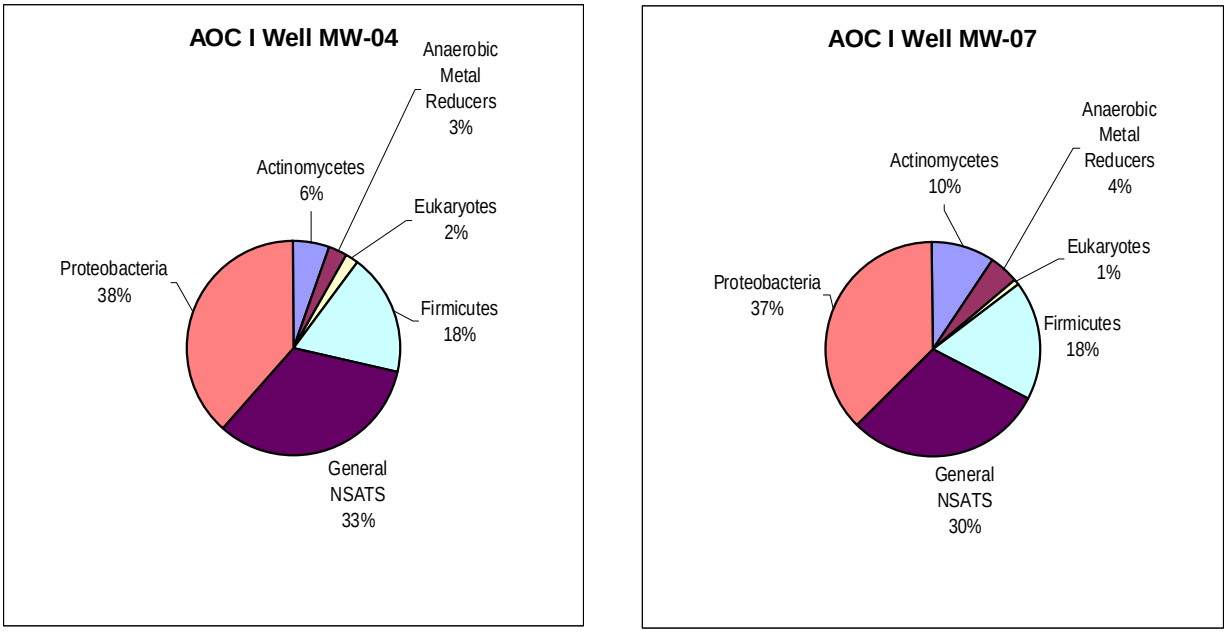
densities determined by PLFA are higher than those determined by culture-based methods. PLFA analyses also report groups that are difficult to grow in vitro or isolated from their microbial consortium. PLFA analysis of groundwater samples from monitoring wells MW-04 and MW-07 indicated a total biomass of 7,960 and 45,100 cells per milliliter (mL), respectively. This is significantly higher than the <1,000 cells/mL typical of un-impacted groundwater, but is considered low for in situ groundwater remediation. Optimization of the microbial environment through the addition of nutrients and electron acceptors in a pilot demonstration could increase the biomass, accelerate biodegradation, reduce toxicity, relieve the stress of growth-limiting factors, and foster microbial diversity.

Community Structure

The initial PLFA analysis provides a baseline from which to compare subsequent measurements after enhancement of the biodegradation environment in the subsurface. Exhibit 1 illustrates the community structure found in monitoring wells MW-04 and MW-07, respectively.

EXHIBIT 1
Community Structures of Monitoring Wells MW-04 and MW-07 at AOC I



Actinomycetes

The unique metabolic capabilities of the fungal-like bacteria known as the Actinomycetes make them important biodegrading organisms. Actinomycetes provide many of the unique biologically active molecules, such as antibiotics, routinely used in medicine. Their presence in the community influences other, competing populations. The group also includes anaerobic sulfate-reducing and iron-reducing bacteria with important biodegradation and energy transfer capabilities. Actinomycetes comprise 6 to 10 percent of the microbial population in this formation.

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Anaerobic Metal Reducers

Microbes that can utilize oxidized metals such as ferric and manganic ions as electron acceptors play an important role in the energy balance in the anaerobic microbial ecosystem where microbes generally survive in cooperative consortia. The presence of microbes capable of anaerobic metal reduction accounts for about 3 to 4 percent of the microbial population and is consistent with field observations of negative oxygen-reduction potential (ORP) and sample analyses showing concentrations of reduced iron and reduced manganese in monitoring wells MW-04 and MW-07.

Eukaryotes

Eukaryotes are microbes more complex than bacteria, and are generally considered the predators and scavengers of the microbial community. Fungi and protozoans are the typical Eukaryotes found in groundwater systems. By inference, their presence indicates the relative health of the microbial community and reflects the abundance of biomass; increasing concentrations of Eukaryotes indicates the prokaryotes population is decreasing due to some growth-limiting or stress factor. Eukaryotes account for 1 to 2 percent of the microbial community.

Firmicutes

Firmicutes are a group of bacteria that lack the secondary outer membrane found in Gram-negative bacteria (such as Proteobacteria, described below). While most Firmicutes have an external cell wall and exhibit a positive or neutral response to Gram staining some have no cell wall and can not be cultured in vitro using techniques available today. Many bacteria in this group produce spores to survive extreme or unfavorable conditions (such as in-situ chemical oxidation [ISCO]) and selected members biodegrade chlorinated solvents and more complex chlorinated organics like polychlorinated biphenyls (PCBs). Firmicutes account for 18 percent of the microbial community.

General Normal Saturated Straight Chain (NSATS)

NSATS fatty acids are common to all microbial groups. The percentage of general NSATS is an inverse indicator of microbial diversity and a direct indicator of ecological stress. Diversity decreases with increasing levels of NSATS. Microbial ecosystems under stress exhibit less diversity. NSATS account for 30 to 33 percent of the fatty acids found in this aquifer.

Proteobacteria

Proteobacteria are Gram-negative bacteria with an outer membrane composed of characteristic lipopolysaccharides. Most species in this group are either facultatively or obligately anaerobic and many exhibit a wide range of biodegradation capabilities. Proteobacteria account for 37 to 38 percent of the microbial community. Because of broad biodegradation potential, dominance of this population group is indicative of a biologically active system well suited for bioremediation.

Physiological Status of Proteobateria

Proteobacteria under stress alter their membrane structure and membrane permeability by modifying the chemical structure of fatty acids in the membrane. PLFA analysis identifies

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and quantifies these fatty acids and provides a profile, expressed as a ratio index, indicative of starvation stress or stress due to environmental factors, such as chemical toxicity. The indices express relative measures based on the ratio of one group of fatty acids to another and are not directly related to the traditional, laboratory growth phases of bacterial culture. Exhibit 2 shows the Proteobacteria PLFA stress indicators and total petroleum hydrocarbons (TPH) data from wells MW-04 and MW-07. Proteobacteria from both wells exhibit the stress indicators associated with growth under limiting conditions; those from well MW-07 exhibited decreased membrane permeability associated with environmental factors.

EXHIBIT 2
Proteobacteria PLFA Stress Indicators and Total Petroleum Hydrocarbons Data from Wells MW-04 and MW-07

	MW-04	**MW-07**
Biomass (cells/mL)	**7,960**	**45,100**
Bacterial Slowed Growth **Stress Index** (ratio)	0.59	1.12
Bacterial Decreased Permeability **Stress Index** (ratio)	0	0.34
TPH-diesel range (mg/L)	<0.5 U	1.20
TPH-gas range (mg/L)	0.67	0.84

cells/mL – cells per milliliter
mg/L – milligrams per liter
TPH – total petroleum hydrocarbons
U - Analyzed for, but not detected

Quantitative Polymerase Chain Reaction (qPCR) of Selected Biomarkers

QPCR is a technique for identifying microbes directly from their DNA and for quantifying specific enzymes in a microbial population. It has the advantage over traditional culturing methods in accuracy, objectivity, and reproducibility. The quantitative analysis can be done on uncultured bacteria, thereby eliminating special growth requirements, growth conditions, and preliminary testing. The presences of key enzymes that activate the initial step in a degradation pathway are considered strong evidence of microbial capabilities for biodegradation potential at a specific site. For aromatic hydrocarbon degradation, three enzymes are generally considered indicative of a microbial community biodegradation potential: Benzylsuccinate Synthase (BSSA) in anaerobic systems and Napthalene Dioxygenase (NDO) and Phenol Monooxygenase (PhMO) in aerobic systems.

For the AOC I groundwater samples, qPCR was used to detect the presence of Dehalobacter, an important biodegradation microbe, and to quantify the presence of three functional enzyme genes: one anaerobic (BSSA) and two aerobic (NDO and PhMO) enzymes.

Indicator Microorganisms: Dehalobacter (qDHB)

Assuming one gene copy per cell, about 2.3 percent of the biomass in well MW-07 is accounted for by Dehalobacter species, an obligate anaerobe capable of biodegrading tetrachloroethylene (PCE) to ethene and chloride by dehalorespiration. Detection of these

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organisms indicates a latent capability for bioremediation that may be dependent on optimization of the environment with nutrients and electron donors/electron acceptors.

Functional Gene: Benzylsuccinate Synthase (BSSA)

BSSA mediated catalysis of toluene and formate to form benzylsuccinate is the initial activation reaction of anaerobic oxidation of the aromatic hydrocarbons toluene and ethylbenzene by anaerobic bacteria. This highly oxygen-sensitive enzyme is commonly associated with sulfate-reducing bacteria. BSSA is the key enzyme of anaerobic toluene degradation and has been found in all anaerobic toluene-degrading bacterial isolates tested. The discovery of significant amounts of BSSA indicates the presence of toluene-degrading microbes functioning under anaerobic conditions.

Functional Gene: Naphthalene Dioxygenase (NDO)

NDO is the initial activation enzyme that catalyzes the cis-dihydroxylation of naphthalene during aerobic biodegradation. NDO also catalyzes the initial oxidation of a wide range of polycyclic aromatic hydrocarbons (PAHs) composed of up to five rings. The absence of this functional gene even though naphthalene is present, supports other data indicating an anaerobic environment.

Functional Gene: Phenol Monooxygenase (PhMO)

PhMO is a key enzyme in phenol activation and participates in the aerobic degradation of TCE. Like NDO, the absence of this functional gene supports other data indicating an anaerobic environment.

Summary

Both the PLFA analysis and the qPCR data support the presence of significant but latent biodegradation capability. PLFA analyses reported a microbial population of 7,960 to 45,100 cells/mL. The microbial ecosystem in both wells is under environmental stress as indicated by the following three indicators

- The percentage of general NSATS relative to other groups of fatty acids suggests limited diversity, an indicator of environmental stress
- Slow growth associated with starvation conditions
- Limited membrane permeability

An abundance of Gram-negative biodegrading organisms prevails along with potential biodegraders from other groups. The percentage of predatory/scavenger Eukaryotes is currently low in both wells and microbial diversity is also low.

qPCR revealed that the prevailing anaerobic conditions suppressed the production of oxidative enzymes NDO and PhMO even though potential substrates are present, below the detection limit, but supported expression of BSSA, the key enzyme responsible for the initial activation reaction of anaerobic degradation of the aromatic hydrocarbons toluene and ethylbenzene.

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Recommendations and Expectations

This aquifer exhibits strong potential for biodegradation however higher levels of biomass lower levels of stress and greater diversity could be express by optimizing the environment. Consider implementing a pilot demonstration to enhance in situ biodegradation by delivering growth and metabolism limiting factors to the aquifer. Schedule a second round of PLFA and qPCR analyses after enhancing bio-attenuation conditions through the addition of electron acceptors and nutrients during a pilot study. Re-evaluation of the biological indicators and markers after the system is adjusted to aerobic conditions should reveal the following:

- Increase in quantities of the function genes NDO and PhMO
- Elimination of BSSA
- Increase in microbial diversity (decrease in the percentage of general NSATS)
- Reduction or elimination of the stress indicators of starvation and limited membrane permeability
- Ultimately a gross reduction in the total biomass to that of the un-impacted aquifer

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Attachment D
Laboratory Analysis

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Laboratory SOPs are proprietary and confidential.
They are provided upon request at the discretion of the Project Manager.

Attachment E
ORC Socks Installation SOP

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REGENESIS

Oxygen Release Compound (ORC®) Installation Instructions

(Replaceable Filter-Sock Application)

ORC Filter Socks are used to enhance bioremediation of petroleum hydrocarbons in groundwater. The filter sock contains ORC and an inert carrier matrix. The socks come in one foot sections. They are laced together to span the vertical polluted saturated zone in monitoring type wells. Once the socks are laced together and lowered into the wells, they become hydrated and begin releasing oxygen. The following instructions are vital to proper installation and subsequent removal of the socks.

SAFETY PRECAUTIONS:

- ORC is completely non-toxic, but is composed of ultra-fine particles.
- Wear dust masks and goggles to prevent soft tissue irritation
- Reference the Material Safety Data Sheet for specific technical and physical information.

CONDITION OF SOURCE WELL:

- Test for well deviation and smoothness before ORC installation.
- For the test, use a 5 foot section of pipe with an outside diameter 1/2 inch smaller than the source well's inside diameter.

KEY REQUIREMENTS FOR INSTALLATION:

- **SOCKS MUST BE INSTALLED WITH BLACK GROMMETS ON TOP**
- Wrap Socks as independent units (see page 3, figure 5)
- A maximum of **20** ea. 2-inch socks per section.
- A maximum of **8** ea. 4-inch socks per section.
- A maximum of **6** ea. 6-inch socks per section.
- Make sure each sock is properly shaped (cylindrical and without bends) to facilitate ease of installation and removal.

HELPFUL HINTS:

- ORC matrix hardens into a cement once hydrated
- Minimize slack between each sock, by periodically pulling up slack while lacing
- Tie off ORC retrieval lines to the well cap. Regenesis recommends the use of a 3/8" diameter x 6" long eyebolt.

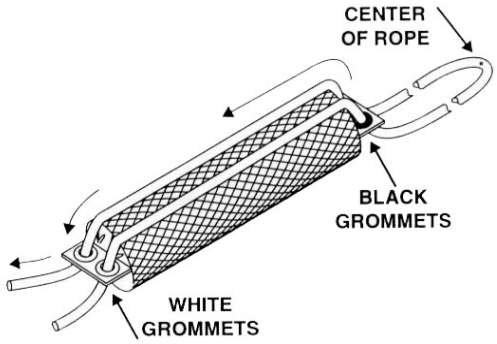
- The ORC Socks should be wetted to prevent excessive dusting prior to installation
- Make sure your work area is clean to avoid oil and dirt deposits on the socks.

FILTER-SOCK REMOVAL:

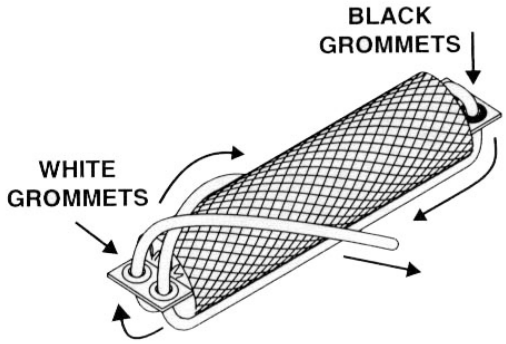
- ORC Socks will be approximately 20% heavier after water saturation
- Static friction from screened casing may cause difficulty in removal
- A winch and stanchion (or comparable equipment) may be necessary to help remove the socks due to increased weight, friction, etc.

LACING DIAGRAMS FOR SOCK INSTALLATION:

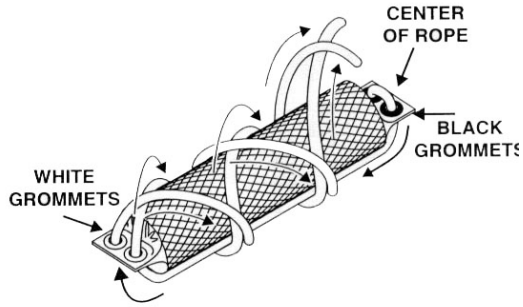
4 INCH AND 6 INCH SOCK LACING DIAGRAM:



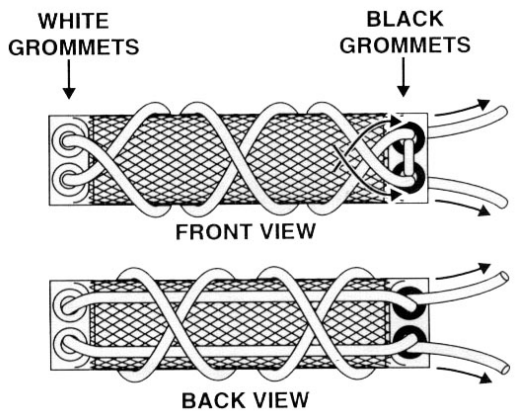
1. Find the center of the rope. Begin lacing the ORC Socks by threading the two ends of the installation rope through the black grommets and then through the white grommets at the bottom of the same side of the bottom sock



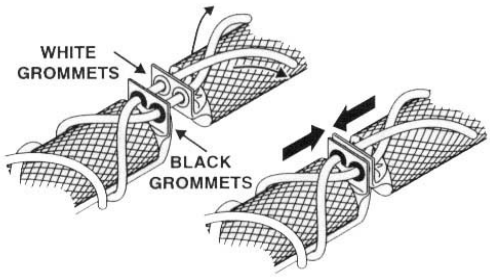
2. Pull the rope through the bottom sock, making sure the center of the rope is between the black grommets. Cross the ropes over each other.



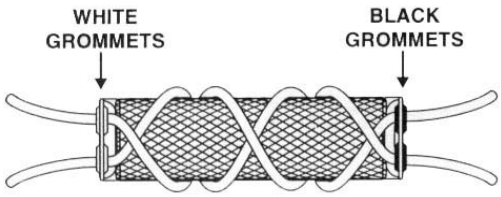
3. Loop the ends of the rope around the back of the sock and cross them. Repeat this step once again, so the rope is wrapped around the sock with two full turns.



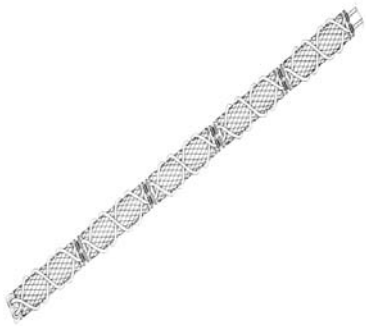
4. Bring the ends of the rope around from the back, cross them, and thread them into the black grommets. The rope ends should be inserted into the black grommets diagonally from the white ones they started from. Threading the black grommets will be tight only on the bottom sock due to the unique lacing pattern.



5. To avoid the ORC Sock slipping past each other, the socks must be laced with the grommet flaps of the bottom sock and second sock butting against each other (as shown)



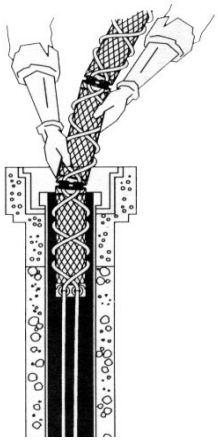
6. The remaining socks on the rope section are laced up according to Figure 6. Make sure that the rope is turned around the sock two full turns, with the grommets of each sock butting up against the next sock as shown in Figure 5.

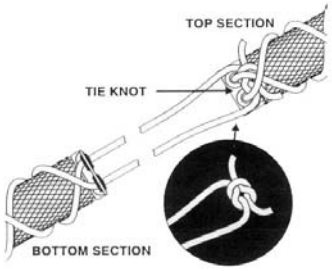


7. Lace each subsequent ORC Sock exactly the same as in Figure 5 and 6.

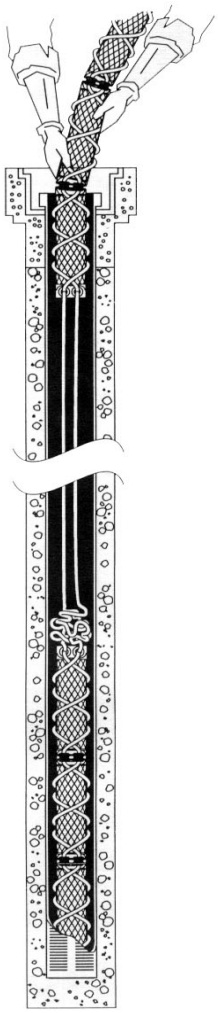
IMPORTANT: *Do not exceed the maximum number of socks per section (see "Key Requirements D & E" on page 1).*

Minimize the slack between the socks



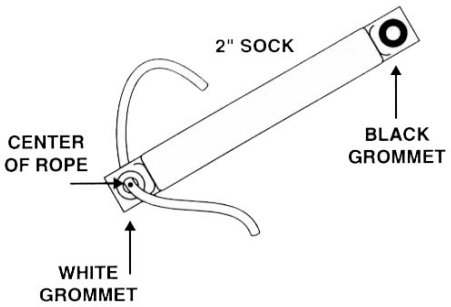


8. If you need to install more ORC Socks than the maximum allowed per well size (see "Key Requirements D & E on page 1), then multiple sections must be installed. Each section is laced exactly the same, but they should be tied off to each other. Tie the end of the rope from the lower section to the bottom sock of the upper section; this allows each section to be installed and removed independently (see well diagram)

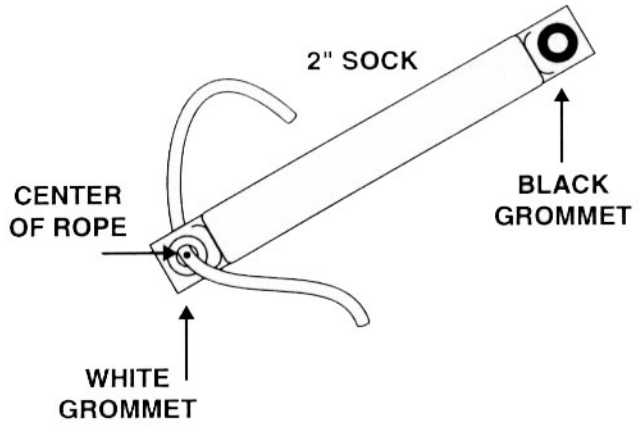


Well Diagram

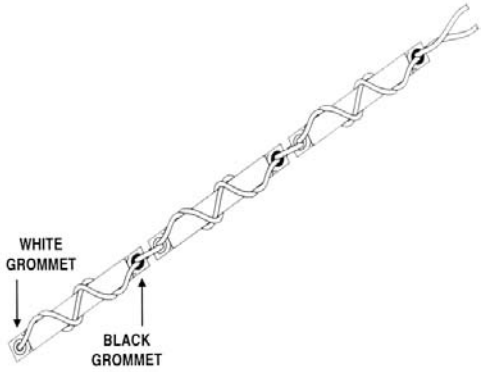
2 INCH SOCK LACING DIAGRAM:



9. Find the center of the rope. Begin lacing the ORC Socks by threading one end of the installation rope through the white grommet. Make sure that the center of the rope is pulled through to the center of the white grommet on the bottom sock.



10. Wrap each end of the installation rope around the sock twice and then cross them through the black grommet.



11. Lace each subsequent sock using the same method ad describe in Figure 2 above.

IMPORTANT:

Do not exceed the maximum number of socks per section (see "Key requirements B" on Page 1) Minimize the slack between socks

For direct assistance or answers to any questions you may have regarding these instructions, contact Regenesis Technical Services at 949-366-8000.

REGENESIS, 2002
www.regenesis.com

Attachment F
Persulfate Field Test SOP

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Sodium Persulfate CHEMets®
0 - 7 & 7 - 70 ppm

Safety Information

Read MSDS before performing this test procedure. Wear safety glasses.

Test Procedure

1. Fill the sample cup to the 25 mL mark with the sample (fig 1).
2. Place the CHEMet ampoule in the sample cup. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill leaving a small bubble to facilitate mixing (fig 2).
3. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time. Wipe all liquid from the exterior of the ampoule. Test results should be obtained **within one minute** after snapping the ampoule tip.
4. Use the appropriate comparator to determine the level of sodium persulfate in the sample. If the color of the CHEMet ampoule is between two color standards, a concentration estimate can be made.
   a. Place the CHEMet ampoule, flat end downward into the center tube of the low range comparator. Direct the top of the comparator up toward a source of bright light while viewing from the bottom. Rotate the comparator until the color standard below the CHEMet ampoule shows the closest match (fig 3).

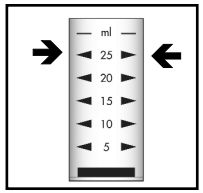

Figure 1

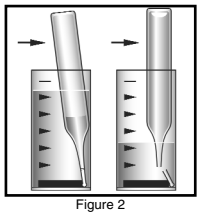
Figure 2

Figure 3

   b. Hold the high range comparator in a nearly horizontal position while standing directly beneath a bright source of light. Place the CHEMet ampoule between the color standards moving it from left to right along the comparator until the best color match is found (fig 4).

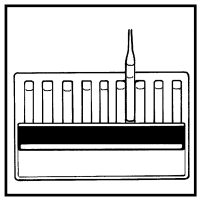
Figure 4

Test Method

The Sodium Persulfate CHEMets®[1] test method employs the ferric thiocyanate chemistry.[2] In an acidic solution, sodium persulfate oxidizes ferrous iron. The resulting ferric iron reacts with ammonium thiocyanate to form ferric thiocyanate, a red-orange colored complex, in direct proportion to the sodium persulfate concentration.

Various oxidizing agents such as hydrogen peroxide, ozone, ferric ions and cupric ions will produce high test results.

1. CHEMets is a registered trademark of CHEMetrics, Inc. U.S. Patent No. 3,634,038
2. D. F. Boltz and J. A. Howell, eds., Colorimetric Determination of Nonmetals, 2nd ed., Vol. 8, p. 304 (1978)

Reorder Information	Cat. No.
***Test Kit**, complete*	*K-7870*
***Refill**, 30 CHEMet ampoules*	*R-7870*
***Sample Cup**, 25 mL, package of six*	*A-0013*
***Comparator**, 0-7 ppm*	*C-7807*
***Comparator**, 7-70 ppm*	*C-7870*

CHEMetrics
Water Analysis Systems

CHEMetrics, Inc., 4295 Catlett Road, Calverton, VA 20138-0214 U.S.A.
Phone: (800) 356-3072; Fax: (540) 788-4856; E-Mail: orders@chemetrics.com
www.chemetrics.com
June 06, Rev. 3

Attachment G
Treatment Chemical Technical Documentation

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OXYGEN RELEASE COMPOUND (ORC®)

ORC is a patented formulation of phosphate-intercalated magnesium peroxide that time releases oxygen when hydrated in accordance with the following reaction:

$$MgO_2 + H_2O \longrightarrow \tfrac{1}{2}O_2 + Mg(OH)_2$$

How it Works

Oxygen is often the limiting factor for aerobic microbes capable of biologically degrading contaminants such as petroleum hydrocarbons. Without adequate oxygen, contaminant degradation will either cease or may proceed by much slower anaerobic (oxygen-free) processes. ORC is designed to release oxygen, into the subsurface, for up to one year depending on site conditions. In the presence of this long-lasting oxygen source, aerobic microbes flourish accelerating natural attenuation of gasoline and fuel additives (BTEX and MTBE), diesel, kerosene, jet fuel, gas condensates, fuel oils, lubricants, bunker oil, PAHs, certain metals (arsenic), certain pesticides/herbicides and certain industrial solvents (alcohols and ketones).

Critical Timed Release

ORC is intercalated with food-grade phosphate, this gives it the time-release properties that are critical in a passive, low-cost oxygen application system. The term "intercalation" is used here to describe the permeation of phosphates into the crystalline structure of magnesium peroxide (Figure 1.). This feature slows the reaction that yields oxygen thus facilitating the extended release. Phosphate intercalation also prevents a process known as "oxygen lock-up." When water reacts with an un-intercalated magnesium peroxide, a cement-like coating of magnesium hydroxide forms which prevents water from penetrating deeper into the crystal to release all of the available oxygen. ORC's phosphate intercalation keeps the crystal "open," preventing this problem and continuing the release of oxygen.

Product Applications

ORC is typically applied in the subsurface via direct push injection, borehole backfill or filter socks. When using direct push and/or borehole backfill, ORC powder is mixed with water to form an injectable slurry. The slurry is then pumped into the groundwater where it disperses into the aquifer via diffusive and advective forces.

In filter sock form, ORC is placed into monitoring wells where the compound reacts when contacted with water. Upon exhaustion, which can take up to 1 year, filter socks can be removed and replaced to replenish the oxygen supply and continue treatment. Special canisters are available with filter socks to avoid lodging them in deeper wells (> 40 ft.).

Additionally ORC can be applied into excavated areas either in its native powder form or by broadcasting the slurry mixture. Excavation treatments take advantage of fluctuating groundwater levels and percolation from the surface to activate the oxygen releasing capabilities of ORC.

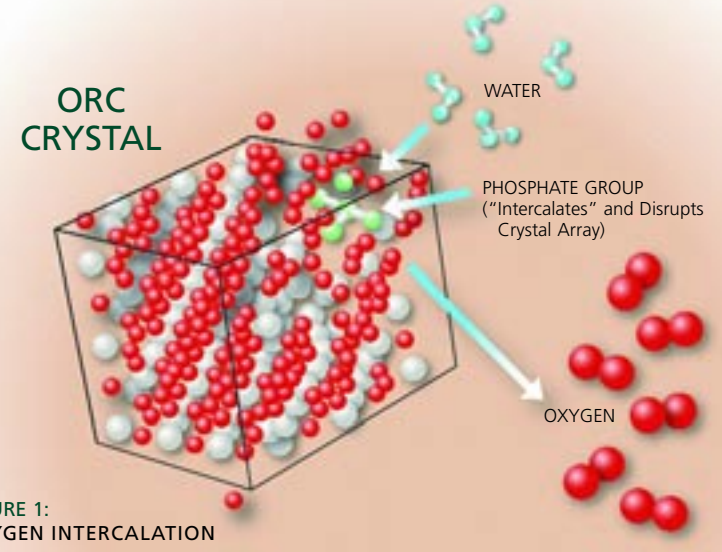

FIGURE 1:
OXYGEN INTERCALATION

ORC®
OXYGEN RELEASE COMPOUND

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Leaders in Accelerated Natural Attenuation

ORC a Cost-Effective Remediation Strategy

By accelerating natural attenuation using ORC, *in-situ* treatment of aquifer contamination can result in an efficient, simple, cost-effective alternative to traditional technologies. With low capital costs, no operations and maintenance, minimal site disturbance and proven effectiveness, this product can inexpensively restore water quality and property values at contaminated sites.

Treatment with ORC is typically:

- 1/4 to 1/2 the cost of air sparging with vapor containment
- Equal to or less than the cost of excavation, hauling and disposal of residual hydrocarbons from the floor of UST excavations
- Less than the long-term monitoring costs of unassisted natural attenuation sites
- 1/4 to 1/2 the cost of using a pump and treat system

Plume Wide Remediation*

The example below illustrates four different size groundwater plumes and four remediation scenarios, including the use of ORC. This comparison assumes a contaminant concentration of 4 ppm total BTEX.

Treatment	Smaller Site (50' x 75')		Larger Site (200' x 200')	
	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)
ORC Treatment	**$58,000**	**$61,000**	**$365,000**	**$380,000**
Pump and Treat	$610,000	$660,000	$1,078,000	$1,200,000
Air Sparging w/SVE	$334,000	$359,000	$619,000	$687,000
Chemical Oxidation	$271,000	$295,000	$1,460,000	$1,600,000

** Comparison costs were generated by an independent environmental consulting firm and include costs through project completion, e.g. sampling, monitoring, reporting, etc. All costs are reported in today's dollars.*

Plume Cut-Off / Barrier Remediation*

The example below illustrates four different size groundwater plumes and four typical, cut-off barrier remediation scenarios, including the use of ORC. This comparison assumes a contaminant concentration of 4 ppm total BTEX.

Treatment	Smaller Site (50' x 75')		Larger Site (200' x 200')	
	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)	Shallow Aquifer (20' bgs)	Deeper Aquifer (50' bgs)
ORC Treatment	**$76,000**	**$82,000**	**$216,000**	**$240,000**
Pump and Treat	$588,000	$636,000	$909,000	$1,009,000
Air Sparging w/SVE	$491,000	$497,000	$832,000	$866,000
Chemical Oxidation	$280,000	$299,000	$1,516,000	$1,630,000

** Comparison costs were generated by an independent environmental consulting firm and include costs through project completion, e.g. sampling, monitoring, reporting, etc. All costs are reported in today's dollars.*

1011 Calle Sombra / San Clemente / California 92673-6244 / Tel: 949/366-8000 / Fax: 949/366-8090 / www.regenesis.com

ORC ADVANCED™

"The Evolution of Controlled Release Oxygen"

ORC Advanced™ is the state-of-the-art technology for stimulating aerobic bioremediation. It offers unparalleled, maximum oxygen release for periods up to 12 months on a single injection and is specifically designed to minimize oxygen waste while maximizing contaminated site remediation.

HOW IT WORKS

Oxygen has been shown to be the limiting factor for microbes capable of aerobically degrading contaminants such as petroleum hydrocarbons.

Without adequate oxygen, contaminant degradation will either cease or may proceed by much slower anaerobic (oxygen-free) processes.

When hydrated, ORC Advanced is designed to release its full amount of oxygen (17% by weight) over a 12 month period. Upon injection into the subsurface, ORC Advanced utilizes its patented **Controlled Release Technology (CRT™)** to deliver its oxygen consistently over an extended period of time, avoiding excessive foaming and oxygen loss seen with commodity chemicals. This enables aerobic microbes to significantly accelerate rates of natural attenuation over long periods of time.

PRODUCT FEATURES AND BENEFITS

Highest Available Oxygen Content

More active oxygen (17%) plus Regenesis' patented CRT™ saves time and money by increasing degradation rates and improving remediation performance by providing more oxygen on a single injection. It is particularly effective at higher demand sites where oxygen may be limited and scavenged by competing carbon sources.

Patented Controlled Release Technology (CRT™)

Based on the same proven technology employed in the industry standard Oxygen Release Compound (ORC®), CRT allows for an efficient, long-term release of oxygen providing the optimal conditions for sustained aerobic biodegradation. This can save time and money by reducing the potential need for multiple applications. Also, oxygen release "lock-up" is avoided – an unfortunate problem experienced with commodity chemicals. (See Details of CRT in Figure 1).

In-Situ Application

Remediation with ORC Advanced is typically more cost-effective than *ex-situ* treatments. With the use of ORC Advanced there is minimal site disturbance with no above-ground piping or mechanical equipment, no operations and maintenance costs and no hazardous materials handling or disposal.

Free Technical Design and Support from Regenesis

Regenesis has been designing and evaluating *in-situ* accelerated bioremediation projects for over 10 years. This "free of charge" service offers the user the highest level of information available on stimulating natural attenuation and ensures a high level of project success.

REGENESIS
Leaders in Accelerated Natural Attenuation

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ORC ADVANCED™
OXYGEN RELEASE COMPOUND

DEFINING THE SCIENCE BEHIND CONTROLLED RELEASE TECHNOLOGY (CRT™)

Early on, Regenesis researchers noted that in order to optimally stimulate the natural attenuation of aerobically degradable contaminants, biologically usable oxygen was best supplied in low but constant concentrations. Big bursts of oxygen are wasteful and simply "bubble off", often generating undesirable foaming and producing unwanted preferential flow paths in the subsurface. Regenesis sought to solve this problem by controlling the rate of oxygen release from solid oxygen sources.

The answer was provided by the development of CRT. The CRT process involves intercalating (embedding) phosphates into the crystal structure of solid peroxygen molecules. This patented feature, now available in the ORC Advanced™ formulation, slows the reaction that yields oxygen within the crystal, minimizing "bubble off" which can waste the majority of oxygen available in common solid peroxygen chemicals.

CRT™ provides "balance" – it slows down the rate of oxygen release while at the same time preventing "lock-up". Commodity solid peroxygen chemicals, when in contact with water, will produce an initial rapid and uncontrolled release of oxygen. Then, as hydroxides form, a significant portion of the oxygen deeper in the crystal is made unavailable or becomes"locked up." This undesirable effect is ineffiecient and costly. CRT prevents lock up and controls the rate of oxygen release, representing the state-of-the-art technology in passive oxygen delivery.

CRT Specifics

Uniformly embedded within the crystalline structure of the peroxygen are phosphate ions. These ions do two important things:

1. they slow the rate of hydration that liberates oxygen thereby creating the CRT effect and
2. they form exit pathways for the oxygen in an otherwise tightly packed crystal that can become even more "locked-up" when hydroxides begin to form as a reaction by-product following oxygen liberation.

This patented process optimizes peroxygen performance and is only available in the Regenesis line of products.

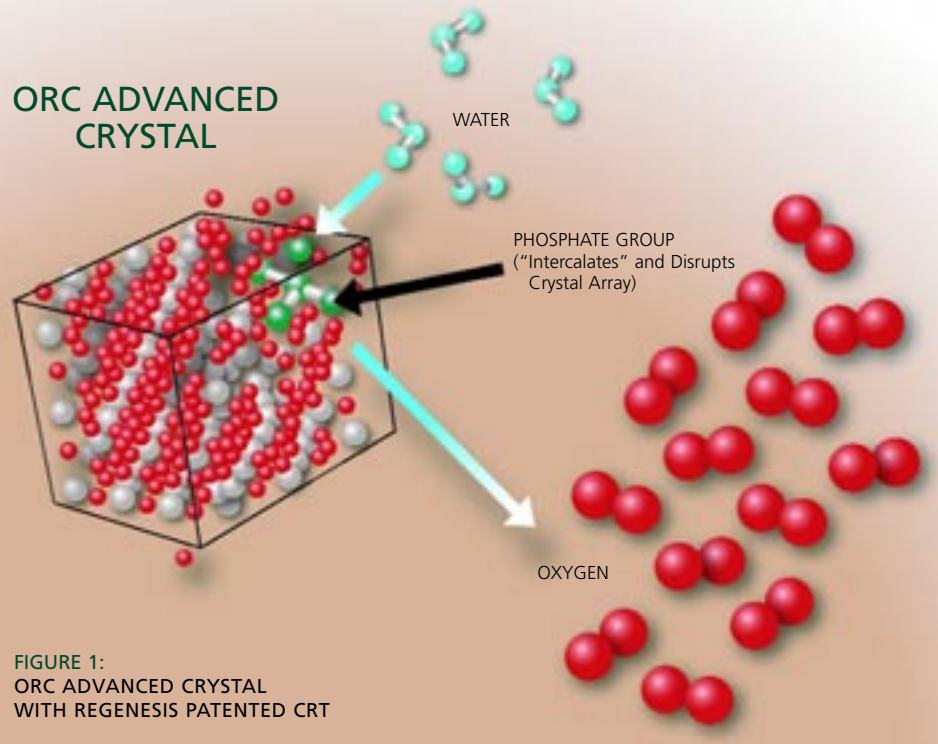

FIGURE 1:
ORC ADVANCED CRYSTAL
WITH REGENESIS PATENTED CRT

For more information or a free project evaluation contact Regenesis at (949) 366-8000 or visit our website at www.regenesis.com

REGENESIS
Leaders in Accelerated Natural Attenuation

Oxygen Release Compound – Advanced (ORC *Advanced*™)
MATERIAL SAFETY DATA SHEET (MSDS)

Last Revised: March 13, 2007

Section 1 - Material Identification

Supplier:

REGENESIS

1011 Calle Sombra
San Clemente, CA 92673

Phone:	**949.366.8000**
Fax:	**949.366.8090**
E-mail:	**info@regenesis.com**

Chemical Description:	A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
Chemical Family:	Inorganic Chemical
Trade Name:	Advanced Formula Oxygen Release Compound (ORC *Advanced*™)
Chemical Synonyms	Calcium Hydroxide Oxide; Calcium Oxide Peroxide
Product Use:	Used to remediate contaminated soil and groundwater (environmental applications)

Section 2 – Composition

CAS No.	Chemical
682334-66-3	**Calcium Hydroxide Oxide [$CaO(OH)_2$]**
1305-62-0	**Calcium Hydroxide [$Ca(OH)_2$]**
7758-11-4	**Dipotassium Phosphate (HK_2O_4P)**
7778-77-0	**Monopotassium Phosphate (H_2KO_4P)**

Section 3 – Physical Data	
Form:	Powder
Color:	White to Pale Yellow
Odor:	Odorless
Melting Point:	527 °F (275 °C) – Decomposes
Boiling Point:	Not Applicable (NA)
Flammability/Flash Point:	NA
Auto- Flammability:	NA
Vapor Pressure:	NA
Self-Ignition Temperature:	NA
Thermal Decomposition:	527 °F (275 °C) – Decomposes
Bulk Density:	0.5 – 0.65 g/ml (Loose Method)
Solubility:	1.65 g/L @ 68° F (20° C) for calcium hydroxide.
Viscosity:	NA
pH:	11-13 (saturated solution)
Explosion Limits % by Volume:	Non-explosive
Hazardous Decomposition Products:	Oxygen, Hydrogen Peroxide, Steam, and Heat
Hazardous Reactions:	None

Section 4 – Reactivity Data

Stability:	Stable under certain conditions (see below).
Conditions to Avoid:	Heat and moisture.
Incompatibility:	Acids, bases, salts of heavy metals, reducing agents, and flammable substances.
Hazardous Polymerization:	Does not occur.

Section 5 – Regulations

TSCA Inventory List:	Listed

CERCLA Hazardous Substance (40 CFR Part 302)

Listed Substance:	No
Unlisted Substance:	Yes
Reportable Quantity (RQ):	100 pounds
Characteristic(s):	Ignitibility
RCRA Waste Number:	D001

SARA, Title III, Sections 302/303 (40 CFR Part 355 – Emergency Planning and Notification)

Extremely Hazardous Substance:	No

SARA, Title III, Sections 311/312 (40 CFR Part 370 – Hazardous Chemical Reporting: Community Right-To-Know

Hazard Category:	Immediate Health Hazard Fire Hazard
Threshold Planning Quantity:	10,000 pounds

Section 5 – Regulations (cont)

SARA, Title III, Section 313 (40 CFR Part 372 – Toxic Chemical Release Reporting: Community Right-To-Know

Extremely Hazardous Substance:	No	
WHMIS Classification:	C	Oxidizing Material Poisonous and Infectious Material
	D	Material Causing Other Toxic Effects – Eye and Skin Irritant
Canadian Domestic Substance List:	Not Listed	

Section 6 – Protective Measures, Storage and Handling

Technical Protective Measures

Storage:	Keep in tightly closed container. Store in dry area, protected from heat sources and direct sunlight.
Handling:	Clean and dry processing pipes and equipment before operation. Never return unused product to the storage container. Keep away from incompatible products. Containers and equipment used to handle this product should be used exclusively for this material. Avoid contact with water or humidity.

Section 6 – Protective Measures, Storage and Handling (cont)

Personal Protective Equipment (PPE)

Engineering Controls:	Calcium Hydroxide ACGIH® TLV® (2000) 5 mg/m^3 TWA OSHA PEL Total dust–15 mg/m^3 TWA Respirable fraction– 5 mg/m^3 TWA NIOSH REL (1994) 5 mg/m^3
Respiratory Protection:	For many conditions, no respiratory protection may be needed; however, in dusty or unknown atmospheres use a NIOSH approved dust respirator.
Hand Protection:	Impervious protective gloves made of nitrile, natural rubbber or neoprene.
Eye Protection:	Use chemical safety goggles (dust proof).
Skin Protection:	For brief contact, few precautions other than clean clothing are needed. Full body clothing impervious to this material should be used during prolonged exposure.
Other:	Safety shower and eyewash stations should be present. Consultation with an industrial hygienist or safety manager for the selection of PPE suitable for working conditions is suggested.
Industrial Hygiene:	Avoid contact with skin and eyes.
Protection Against Fire & Explosion:	NA

Section 7 – Hazards Identification

Emergency Overview:	Oxidizer – Contact with combustibles may cause a fire. This material decomposes and releases oxygen in a fire. The additional oxygen may intensify the fire.
Potential Health Effects:	Irritating to the mucous membrane and eyes. If the product splashes in ones face and eyes, treat the eyes first. Do not dry soiled clothing close to an open flame or heat source. Any

	clothing that has been contaminated with this product should be submerged in water prior to drying.
Inhalation:	High concentrations may cause slight nose and throat irritation with a cough. There is risk of sore throat and nose bleeds if one is exposed to this material for an extended period of time.
Eye Contact:	Severe eye irritation with watering and redness. There is also the risk of serious and/or permanent eye lesions.
Skin Contact:	Irritation may occur if one is exposed to this material for extended periods.
Ingestion:	Irritation of the mouth and throat with nausea and vomiting.

Section 8 – Measures in Case of Accidents and Fire

After Spillage/Leakage/Gas Leakage:	Collect in suitable containers. Wash remainder with copious quantities of water.
Extinguishing Media:	See next.
Suitable:	Large quantities of water or water spray. In case of fire in close proximity, all means of extinguishing are acceptable.
Further Information:	Self contained breathing apparatus or approved gas mask should be worn due to small particle size. Use extinguishing media appropriate for surrounding fire. Apply cooling water to sides of transport or storage vessels that are exposed to flames until the fire is extinguished. Do not approach hot vessels that contain this product.
First Aid:	After contact with skin, wash immediately with plenty of water and soap. In case of contact with eyes, rinse immediately with plenty of water and seek medical attention. Consult an opthalmologist in all cases.

Section 8 – Measures in Case of Accidents and Fire

Eye Contact:	Flush eyes with running water for 15 minutes, while keeping the eyelids wide open. Consult with an ophthalmologist in all cases.
Inhalation:	Remove subject from dusty environment. Consult with a physician in case of respiratory symptoms.

Ingestion:	If the victim is conscious, rinse mouth and admnister fresh water. DO NOT induce vomiting. Consult a physician in all cases.
Skin Contact:	Wash affected skin with running water. Remove and clean clothing. Consult with a physician in case of persistent pain or redness.
Special Precautions:	Evacuate all non-essential personnel. Intervention should only be done by capable personnel that are trained and aware of the hazards associated with this product. When it is safe, unaffected product should be moved to safe area.
Specific Hazards:	Oxidizing substance. Oxygen released on exothermic decomposition may support combustion. Confined spaces and/or containers may be subject to increased pressure. If product comes into contact with flammables, fire or explosion may occur.

Section 9 – Accidental Release Measures

Precautions:	Observe the protection methods cited in Section 3. Avoid materials and products that are incompatible with product. Immediately notify the appropriate authorities in case of reportable discharge (> 100 lbs).
Cleanup Methods:	Collect the product with a suitable means of avoiding dust formation. All receiving equipment should be clean, vented, dry, labeled and made of material that this product is compatible with. Because of the contamination risk, the collected material should be kept in a safe isolated place. Use large quantities of water to clean the impacted area. See Section 12 for disposal methods.

Section 10 – Information on Toxicology

Toxicity Data

Acute Toxicity:	Oral Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Dermal Route, LD_{50}, rat, > 2,000 mg/kg (powder 50%) Inhalation, LD_{50}, rat, > 5,000 mg/m^3 (powder 35%)
Irritation:	Rabbit (eyes), severe irritant

Sensitization:	No data
Chronic Toxicity:	In vitro, no mutagenic effect (Powder 50%)
Target Organ Effects:	Eyes and respiratory passages.

Section 11 – Information on Ecology

Ecology Data	
	10 mg $Ca(OH)_2$/L: pH = 9.0 100 mg $Ca(OH)_2$/L: pH = 10.6
Acute Exotoxicity:	Fishes, Cyprinus carpio, LC_{50}, 48 hrs, 160 mg/L Crustaceans, Daphnia sp., EC_{50}, 24 hours, 25.6 mg/L (Powder 16%)
Mobility:	Low Solubility and Mobility
Abiotic Degradation:	Water – Slow Hydrolysis. Degradation Products: Calcium Hydroxide Water/soil – complexation/precipitation. Carbonates/sulfates present at environmental concentrations. Degradation products: carbonates/sulfates sparingly soluble
Biotic Degradation:	NA (inorganic compound)
Potential for Bioaccumulation:	NA (ionizable inorganic compound)

Section 11 – Information on Ecology (cont)

Comments:	Observed effects are related to alkaline properties of the product. Hazard for the environment is limited due to the product properties of: • No bioaccumulation • Weak solubility and precipatation as carbonate or sulfate in an aquatic environment. Diluted product is rapidly neutralized at environmental pH.
Further Information:	NA

Section 12 – Disposal Considerations

Waste Disposal Method:	Consult current federal, state and local regulations regarding the proper disposal of this material and its emptied containers.

Section 13 – Shipping/Transport Information

D.O.T Shipping Name:	Oxidizing Solid, N.O.S [A mixture of Calcium OxyHydroxide [$CaO(OH)_2$] and Calcium Hydroxide [$Ca(OH)_2$].
UN Number:	1479
Hazard Class:	5.1
Label(s):	5.1 (Oxidizer)
Packaging Group:	II
STCC Number:	4918717

Section 14 – Other Information

HMIS® Rating	Health – 2 Flammability – 0	Reactivity – 1 PPE - Required

HMIS® is a registered trademark of the National Painting and Coating Association.

NFPA® Rating	Health – 2 Flammability – 0	Reactivity – 1 OX

NFPA® is a registered trademark of the National Fire Protection Association.

Reason for Issue: Update toxicological and ecological data

Section 15 – Further Information

The information contained in this document is the best available to the supplier at the time of writing, but is provided without warranty of any kind. Some possible hazards have been determined by analogy to similar classes of material. The items in this document are subject to change and clarification as more information become available.

FMC

Environmental Solutions

KLOZUR™
Power. Stability. Versatility.

Technical Bulletin

FMC's patent pending activation chemistries provide unrivaled power and performance in the subsurface for ISCO applications

Klozur™ sodium persulfate upon activation generates the sulfate radical (SO_4^{-}•), a very strong oxidant capable of oxidizing a broad range of recalcitrant compounds of concern (CoC's). Although heat or Fe(II) salts can be used to activate persulfate, heat activation may not be a practical solution, and the performance of Fe(II) may be hindered by availability in the groundwater. FMC has tested certain chemical activators, which in combination with **Klozur**™ persulfate destroy many of the most recalcitrant compounds. FMC has patents pending for use of combinations of these chemical activators with persulfate. These activator chemistries for **Klozur ™** persulfate include:

- **Chelated Metal Activators** — Improved transportability
- **H_2O_2 Activation** — Dual oxidant combination for oxidation of recalcitrant CoC's
- **Alkaline Activation** — pH control for the formation of energetic persulfate radicals

Choosing the right chemical activator for use with **Klozur ™** persulfate is a function of several factors, including the effectiveness against CoC's and subsurface conditions. Table 1 shows the general effectiveness of the activated persulfate chemistries for various classes of CoC's, as determined in aqueous solutions under laboratory conditions (heat and Fe(II) activation methods also included).

Chemistry	BTEX	chlorinated ethenes	chlorinated ethanes	MTBE	PCB	1,4-dioxane
Un-activated Sodium Persulfate	Y	N	N	N	N	N
Sodium Persulfate + Fe(II)	Y	Y	N	Y	?	Y
Sodium Persulfate + Heat	Y	Y	Y	Y	Y	Y
Klozur™ Activated Persulfate with Chelated Metals	Y	Y	N	Y	?	Y
Klozur ™ Activated Persulfate with Hydrogen Peroxide Activation	Y	Y	Y	Y	?	?
Klozur ™ Activated Persulfate with Alkaline Activation	Y	Y	Y	Y	Y	Y

Table 1: General Effectiveness of "Klozur™ Persulfate" Activator Chemistries for Broad Classes of Contaminants of Concern (Y – generally effective, N – generally not effective, ? – data not yet available).

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Document: 03-03-AOD-DD. For questions, please contact the Environmental Industry Team (EIT) at 866-860-4760.

FMC

Environmental Solutions

For **Klozur™** persulfate ordering information, please contact:

Customer Service
Voice: 800-345-2701
Fax: 215-299-6612

For technical information, please contact:

Philip Block, Ph.D.
Technology Manager
215-299-6645

Frank C. Sessa, M.S.
Technologist
215-299-5993

For sales information, please contact:

Scott Steffl
Commercial Manager
215-299-6031

Linda Osborne
Technical Sales Manager
815-228-1306

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50 lbs/
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RIG K 123 1033

50 LBS. NET WT. (22.7 kg)

YARA

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15.5-0-0+19Ca

Guaranteed Analysis
Total Nitrogen (N) 15.5%
1.0% Ammoniacal Nitrogen
14.5%Nitrate Nitrogen
Calcium (Ca).....19.0%

Derived from Ammonium Calcium Nitrate Double Salt.

Guaranteed by:
Yara North America, Inc.
100 North Tampa Street, Suite 3200
Tampa, FL 33602
For Yara International ASA, Norway

Use in accordance with recommendations of a qualified individual or institution, such as, but not limited to, a certified crop advisor, agronomist, university crop extension publication, or apply according to recommendations in your approved nutrient management plan.

Not a DOT regulated product 49 CFR 171.102
Special provision 34 specifically removes the calcium nitrate double salt (calcium nitrate and ammonium nitrate) from the hazardous materials table 49 CFR 171.101.

"THERE ARE NO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS WITH RESPECT TO THESE PRODUCTS, NOR ARE THERE ANY EXPRESSED WARRANTIES OTHER THAN AS MAY BE CONTAINED IN ANY GUARANTEED ANALYSIS THAT MAY ACCOMPANY THE PRODUCT. BUYER ASSUMES ALL RISK TO PERSON AND PROPERTY IN THE USE, HANDLING OR STORAGE OF THE PRODUCT. SELLER'S LIABILITY IS LIMITED TO THE FULL AMOUNT OF THE PURCHASE PRICE, WITH THE WAIVER OF ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES BEING AN EXPRESSED PROVISION OF THIS SALE."

FIRST AID

CAUTION: MINERAL FERTILIZERS ARE INORGANIC SALTS OR MIXTURES OF SALTS. BY THEIR NATURE, FERTILIZER SALTS MAY BE IRRITATING TO THE SKIN AND EYES. PRECAUTIONS SHOULD BE TAKEN TO PREVENT EYE CONTACT AND MINIMIZE SKIN CONTACT. FERTILIZER DUSTS ARE CONSIDERED NUISANCE-TYPE DUSTS. INHALATION OF NUISANCE DUSTS MAY INDUCE OR AGGRAVATE RESPIRATORY DISCOMFORT. APPROVED DUST RESPIRATORS SHOULD BE USED WHEN FERTILIZER DUST IS PRESENT. WHEN HANDLING FERTILIZERS IN ENCLOSED AREAS, ADEQUATE VENTILATION SHOULD BE EMPLOYED TO MOVE DUST.
SKIN: FLUSH WITH WATER AND WASH THOROUGHLY WITH SOAP AND WATER, REPEAT AS NECESSARY.
EYES: FLOOD WITH CLEAN WATER IMMEDIATELY FOR AT LEAST 15 MINUTES, REPEAT AS NECESSARY.
INGESTION: GIVE WATER, MILK, OR ACTIVATED CHARCOAL TO DELAY ABSORPTION OF INGESTED NITRATE. REMOVE INGESTED FERTILIZER BY INDUCED VOMITING OR GASTRIC LAVAGE.
IN ALL CASES OF DISCOMFORT DUE TO EXPOSURE, SEEK MEDICAL ATTENTION.

HANDLE THIS PRODUCT PROPERLY.
TO ASSURE OPTIMUM QUALITY AND PERFORMANCE:
USE CLEAN, DRY AND WELL MAINTAINED EQUIPMENT

Information regarding the contents and levels of metals in this product is available on the internet at http://www.aapfco.org/metals.htm.

Warning: This product contains a chemical (or chemicals) known to the State of California to cause cancer and birth defects or other reproductive harm.

Yara offers a wide spectrum of fertilizer products. For higher quality, yield and profits, use Yara.

Nitrates

NK/NPKs

Commodities

Also available from Yara:
- Potassium Sulfate
- Slow Release
- Micronutrients

Questions/Information

Customer Service:
800-234-9376

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Yara Specialties
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LDPE

Attachment H
Injection Point SOP

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STANDARD OPERATING PROCEDURE A-7

Temporary Injection Points

I. Purpose and Scope

Provide guidelines for installing subsurface temporary injection points for injection of soil treatment fluids.

II. Equipment and Materials

- Personal Protection Equipment
- Geoprobe or direct push rig with the capability of installing well screen and riser.
- 1-inch ID schedule 40 PVC
- 1-inch 0.020-inch factory slotted screen

III. Procedures and Guidelines

All personnel shall be wearing PPE per HASP. Decontaminate all equipment per SOP "*Decontamination of Drilling Rigs and Equipment*." Locate and record the injection point in the logbook. Draw a diagram of the injection point array and local landmarks with sufficient angle and distance measurements to permanently fixed objects that the location of the injection array can be re-established later if needed. On completion and abandonment of borehole, install PVC stake identifying the location for future reference.

Using a Geoprobe/direct push rig, push 3.5-inch rods down to the bottom depth of the interval to be injected. Install 1-inch ID screen and riser. The screen interval should fully penetrate the interval to be injected. Use a Morie number 2 sand or equivalent to backfill the screen zone to approximately 2 feet above the screen zone. Install a bentonite seal from the top of the filter pack to approximately 2 feet above the top of the filter pack. Install a bentonite cement grout from the top of the bentonite grout seal to just below ground surface. A flush mount protective casing or secure vault will be installed to secure the injection point.

IV. Key Checks and Preventative Maintenance

- Thorough decontamination of all equipment.
- Make sure well materials don't bridge. Measure volumes installed, and calculate borehole volume to confirm no bridging. Measure well materials in the borehole as they are installed.

Attachment I
Sampling Nomenclature

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Station Identification System

Field station data are information assigned to a physical location in the field at which some sort of sample is collected. For example, a monitoring well that has been installed will require a name that will uniquely identify it with respect to other monitoring wells or other types of sample locations. The station name provides a key in a database to which any samples collected from that location can be linked to form a relational database structure.

Before beginning fieldwork, the Field Team Leader will review the proposed level of effort and coordinate a list of unique station identification names, or station IDs, with the Data Management Coordinator (DMC). The Field Team Leader will be responsible for enforcing the use of the standardized numbering system during all field activities.

Each station will be uniquely identified by an alphanumeric code that will describe the station's attributes. These attributes are Facility, Area of Concern (AOC)/Site/Operable Unit (OU) number, Location type, sequential Location number, and possibly an additional qualifier. The naming scheme that will be used to identify a sampling location is documented in Table 1.

This station designation format will be followed throughout the field activities conducted. Required deviations to this format in response to field conditions will be documented in the field logbook.

Sample Identification System

Field sample data are information assigned to a physical piece of material collected in the field for which some sort of analysis will be run. Before collecting samples the Field Team Leader will review the proposed level of effort and coordinate a list of unique sample identification names, or sample IDs, with the DMC.

A standardized numbering system will be used to identify all samples collected during sampling activities. The numbering system will provide a tracking procedure to ensure accurate data retrieval of all samples taken. A listing of the sample identification numbers will be maintained by the Field Team Leader, who will be responsible for enforcing the use of the standardized numbering system during all sampling activities. Sample identification for all samples collected during the investigations will use the format described below.

Each normal and duplicate sample will be uniquely identified by an alphanumeric code that will describe the sample's attributes. These attributes are Facility, AOC/Site/OU number, Location type, sequential Location number with possibly an additional qualifier, depth (as applicable) and date. Each field QC sample will also be uniquely identified by an alphanumeric code that will describe the sample's attributes. These attributes are Qualifier Code, Qualifier Number, and Date. Each unique set of sample attributes will be assigned a unique sample name. The naming scheme that will be used to identify a field sample is documented in Table 2.

This sample designation format will be followed throughout the field activities conducted. Required deviations to this format in response to field conditions will be documented in the field logbook.

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Table 1 – Station ID Scheme
Navy Clean

First Segment	Second Segment	
Facility, Site Number	Station Type	Station Number, Modifier
AA,ANN	AA	NNN_A

Notes: "A"= alphabetic "N"= numeric

Facility:

A = ABL
AN = Anacostia
BA = Bainbridge
BW = Bloodsworth Island
BO = Bolling AFB
BR = Bremerton
CA = Cheatham Annex
CH = Cherry Point
CI = Craney Island
CL = Camp Lejeune
CP = Camp Peary
CR = Carderock
DA = Dahlgren
DN = Dam Neck
DR = Driver
IH = Indian Head
LS = Little Creek
NA = Naval Academy
NB = Naval Station Norfolk
NM = NNMC (Bethesda Naval Hospital)
NN = Norfolk Naval Shipyard
NR = Naval Research Laboratory
NWA = Northwest Annex
OC = Oceana
PA = Pax River
PI = Pineros Islands
Q = Quantico
RO = Rota
RR = Roosevelt Roads
SI = Sigonella
SJ = St. Juliens
SS = Sabana Seca
VE = Vieques East
VW = Vieques West
WN = Washington Navy Yard
WO = White Oak
Y = Yorktown

Site/AOC/SWMU Number – Sequential Number:

Site = S01, S02, S03…
Site Screening Area = SA01, SA02, SA03…
AOC = A01, A02, A03…
AOI = AI01, AI02, AI03…
SWMU = W01, W02…
Building = B01, B02, B03…
R01 = MWR Skeet Range
M01 = Marine Pistol and Rifle Range
LIA – LI Area, East Vieques

BSxx = Background locations outside of site (BS25 = Background Site 25)
BKL = Background locations outside of the facility
BKG = Background locations (inside base)

YNWS = Yorktown QC Samples Only
CHAX = Cheatham Annex QC Samples Only
SESA = Sabana Seca QC Samples Only
CAP = Camp Peary QC Samples Only

Station Type:

AGT = Above Ground Tank
AS = Ash
BH = Borehole
DP = Direct Push
DR = Drill Rig
EW = Extraction Well
FG = Frog
FS = Fish
GB = Geotechnical Boring
GP = Geoprobe
GV = Gas Vent
HP = Holding Pond/Lagoon
IW = Injection Well
LW = Leach Well
MA = Alluvial Monitoring Well
MB = Bedrock Monitoring Well
MU = UST Monitoring Well
MW = Monitoring Well (GW for Y)
PC = Paint Chip
PW = Production Well
RK = Rock
SW = Surface Water
RC = Recovery Well
RM = Remediation Well
RW = Residential Well
SD = Sediment Location
SG = Soil Gas
SL = Storm Sewer Line Sediment
SO = Soil Location
SP = Seep
ST = StormWater
SU = Sump
SV = Soil Vapor
SW = Surface Water
SWS = Surface Water Body (for SW and SD)
UST = Underground Storage Tank
TA = Tap Water
TD = Tidal Station
TI = Tissue Sample (general)
TO = Tadpole
TP = Test Pit
TR = Trench Sediment
TS = Treatment System
TW = Temporary Well
WA = Alluvial Extraction Well
WB = Bedrock Extraction Well
WL = Water Supply Well
WN = Pore Water
WP = Wipe Sample
WT = Water Table Piezometer
IDW = Investigation Derived Waste
QC = QA/QC blanks only

Station Number:
Sequential Station Number (i.e., 001, 002, 003…)

Modifier (used selectively):
D = Deep monitoring well
S = Shallow monitoring well

Example Station IDs:

YS01-DP002 = Direct push soil location #2 at Yorktown Naval Weapons Station Site 1
CHR05-MW002S = Shallow monitoring well location 2, at the Cheatham Annex facility, Range 5.
NMBKL-SD002 = Background sediment location #2 located outside of NNMC
CHBS03-SO05 = Soil location #5, located in reference area outside of Site 3 in Cherry Point

***Notes:* Location ID for any QA/QC blank samples (trip blanks, field blanks, equipment rinse blanks) will be Facility -QC and Facility–IDW for any IDW samples. The first segment indicates the Site ID.

Table 2 – Sample ID Scheme
Navy Clean

First Segment	Second Segment	Third Segment	Fourth Segment
Site ID Facility, AOC Number	Station/Sample Type, Station Number, Modifier	Depth (As Needed)	Date (MMYY) $_A$
AA,ANN	AANNN$_A$	A	NNNN$_A$

Notes: "A"= alphabetic "N"= numeric

A = ABL
AN = Anacostia
BA = Bainbridge
BW = Bloodsworth Island
BO = Bolling AFB
BR = Bremerton
CA = Cheatham Annex
CH = Cherry Point
CI = Craney Island
CL = Camp Lejeune
CP = Camp Peary
CR = Carderock
DA = Dahlgren
DN = Dam Neck
DR = Driver
IH = Indian Head
LS = Little Creek
NA = Naval Academy
NB = Naval Station Norfolk
NM = NNMC (Bethesda Naval Hospital)
NN = Norfolk Naval Shipyard
NR = Naval Research Laboratory
NWA = Northwest Annex
OC = Oceana
PA = Pax River
PI = Pineros Islands
QU = Quantico
RO = Rota
RR = Roosevelt Roads
SI = Sigonella
SJ = St. Juliens
SS = Sabana Seca
VE = Vieques East
VW = Vieques West
WN = Washington Navy Yard
WO = White Oak
Y = Yorktown

Site/AOC/SWMU – Sequential Number:

Site = S01, S02, S03…
Site Screening Area = SA01, SA02, SA03…
AOC = A01, A02, A03…
AOI = AI01, AI02, AI03…
SWMU = W01, W02…
Building = B01, B02, B03…
R01 = MWR Skeet Range
M01 = Marine Pistol and Rifle Range
LIA – LI Area, East Vieques

BSxx = Background locations outside of site (BS25 = Background Site 25)
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SESA = Sabana Seca QC Samples Only

Sample Type:
AGT = Above Ground Tank
AH = Air - Headspace
AS = Ash
BH = Borehole
DR = Drill Rig
DS = Direct Push—Soil
DW = Direct Push—Groundwater
EW = Extraction Well
FG = Frog
FS = Fish
GB = Geotechnical Boring
GP = Geoprobe
GV = Gas Vent
HP = Holding Pond/Lagoon
IW = Injection Well
LF = Free Product
LW = Leach Well
MA = Alluvial Monitoring Well
MB = Bedrock Monitoring Well
MU = UST Monitoring Well
MW = Monitoring Well (GW for Y)
PC = Paint Chip
PW = Production Well
RK = Rock
SW = Surface Water
RC = Recovery Well
RM = Remediation Well
RW = Residential Well
SB = Subsurface Soil
SD = Sediment Location
SG = Soil Gas
SL = Storm Sewer Line Sediment
SO = Soil Location (Composite)
SP = Seep
SS = Surface Soil
ST = StormWater
SU = Sump
SV = Soil Vapor
SW = Surface Water
UST = Underground Storage Tank
TA = Tap Water
TD = Tidal Station
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TS = Treatment System
TW = Temporary Well
WA = Alluvial Extraction Well
WB = Bedrock Extraction Well
WL = Water Supply Well
WN = Pore Water
WP = Wipe Sample
WT = Water Table Piezometer

Station Number:
Sequential Number (e.g., 001, 002, 003)

Modifier (used selectively):
D = Deep monitoring well
S = Shallow monitoring well
P = Duplicate

Depth:

Use only if applicable. A sequential letter is used to reflect varying depths, as actual depths can change in the field after sample planning has occurred. E.g. A, B, C…

Sample Number:

1. Duplicate Samples - Use a 'P' modifier in the second segment of the sample ID, directly after the location number to indicate a duplicate sample. E.g. AB01-MW11P-0506

2. QC & IDW Samples (Blank Samples & Waste Char.) - Format consists of Facility, AOC Number, Qualifier Code, Sequential Qualifier Number-Date (AAANN-AANN-MMDDYY). E.g. LSA05-TB02-061106

Qualifier Codes:
TB = Trip Blank
FB = Field Blank
EB = Equipment Blank
WS = Waste Char. Soil
WW = Waste Char. Water

3. Drill Rig Samples – Format consists of Facility, AOC Number, Station Type, Station Number, Date. E.g. YS12-DR02-020507

4. Multiple samples - Should multiple samples be collected from the same location in a given day/month (affects only samples not differentiated by depth), a sequential letter will be added to the end of the fourth segment (date). E.g. A, B, C…

Example Sample IDs:

PAS02-DS003-C-0805 = Direct push soil sample collected at location 3, in OU2 at the Pax River facility, from the third depth collected below ground surface (BGS) in August 2005.
NBBKL-SS011-0403 = Surface soil collected at location # 11, at a background location outside of Naval Station Norfolk in April 2003.
WNA01-MW102S-0105A = The first shallow groundwater sample collected at monitoring well location 102 in January 2005 in AOC01 at the Washington Navy Yard facility.
PIW01-SW023P-0306 = Pineros Island duplicate surface water sample collected at location 23 from SMWU-1 in March 2006.
SSW06-FB01-061106 = The first field blank collected on June 11, 2006 at SMWU-6 in Sabana Seca.

Attachment J
Response to Comments

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Final Responses to
EPA Comments
Draft In-Situ Remediation Pilot Studies (AOC E and AOC I Sites)
Sampling and Analysis Plan
Former Naval Ammunition Support Detachment
Vieques, Puerto Rico
SAP Date June 2009

General Comments:

1. **The Draft In-Situ Remediation Pilot Studies (AOC E and AOC I Sites), Sampling and Analysis Plan, Former Naval Ammunition Support Detachment, Vieques, Puerto Rico, dated June 2009 (Pilot Studies SAP) does not provide complete information regarding implementation of the proposed technologies. Issues that should be considered and evaluated in a complete work plan include:**

   - **appropriate technical documentation of the specific products to be used, including application procedures, and documentation supporting suitability for the current site conditions; and**
   - **identification of potential risks associated with these remedial technologies (e.g. potential interferences among the remedies) and how they will be prevented or identified and resolved.**

   Provide additional technical documentation of the proposed products to document their suitability at the proposed sites and allow for management of risks associated with the proposed activities.

   Navy Response:

   The majority of the requested information appears to have already been included in the following specific Worksheets or Appendices of the Draft Pilot Studies SAP. Specifically:

   - Pertinent background information that provides the rationale for the pilot study and associated approach are provided in Worksheets 10 and 11.
   - The project scope of work (SOW) and injection protocols (including injectate quantity, delivery methods, injection flow rate and pressure, sampling requirements etc.) for the proposed nitrate injection in unsaturated soil (for AOC E only), persulfate injection in groundwater (for both AOC E and AOC I), and enhanced in-situ bioremediation using ORC socks (for both AOC E and AOC I) were detailed in Worksheets 14a and Worksheets 14b (from page 63 to page 72 in the Draft SAP).
   - The sampling schedules regarding baseline and post-injection performance sampling were described in Worksheets 16a-1, 16a-2, and 16b. The specific soil and groundwater sampling locations and sampling methods were detailed in Worksheets 18a-1, 18a-2, and 18b.

- Material Safety Data Sheets (MSDSs) of the proposed products (iron-EDTA, Klozur® sodium persulfate, and ORC) were included in Attachment B. The instructions on how to install the ORC socks were included in the Attachment E

In addition to the above, the following have been added in response to EPA's comment:

- Reference to the MSDSs of the proposed products (iron-EDTA, Klozur® sodium persulfate, and ORC) has been added to Worksheet 10a, Pilot Study Approach, after the third sentence. Reference to the ORC sock installation instructions has been added to Worksheet 14a, Installation of ORC Socks (EISB).

- Additional information on the Viking Ship® Brand CALCINITTM calcium-nitrate product has been included as Attachment G, and referenced in Worksheet 14a, Nitrate injection in Unsaturated Zone Soil. Additional technical literature for products Klozur® sodium persulfate, and ORC has also been included in Attachment G. Reference to the Klozur® sodium persulfate product technical literature in Attachment G has been added to Worksheet 14a, Persulfate Injection in Groundwater (ISCO). Reference to the ORC technical literature has been added to Worksheet 14a, Installation of ORC Socks (EISB).

- The following paragraph has been added after the last bullet of Injection Protocol in the Nitrate Injection in Unsaturated Zone Soil section of Worksheet 14a: "The proposed unsaturated zone soil treatment using denitrification based bioremediation (DBB) should reduce the naphthalene concentrations in the unsaturated zone soil through enhanced anaerobic degradation, thereby reducing or eliminating the soil-to-groundwater leaching potential. This technology should not destroy the binding (adsorption) between the soil organic materials and COCs; therefore, it should not increase the potential for residual NAPL mobilization. A buffering infiltration and treatment zone (26 to 32 ft bgs) below the nitrate injection depth zone (16 to 26 ft bgs) will allow further reductions of COC concentrations by denitrification. Should residual COC reach the water table, these COCs will be treated by the proposed persulfate ISCO and subsequent ORC treatments."

- The following paragraph has been added at the end of the Installation of ORC Socks (ESIB) section of Worksheet 14a:"The proposed EISB involving ORC socks will be a polishing step following the persulfate ISCO treatment for the groundwater, and will serve to enhance, not interfere with, the processes initiated by ISCO treatment. In fact, the ISCO treatment might improve the efficiency and longevity of the EISB due to the potential to have residual high ORP and dissolved oxygen from the ISCO that could result in lower oxygen demand by the groundwater. Therefore, the combination of the proposed treatment technologies is likely to have a synergistic affect, with very low risk of interference."

2. **The AOC E SAP does not describe any measurements of the oxidant demand, and whether the oxidant demand is solely due to the hydrocarbon release or if there is background oxidant demand that will restore the saturated zone to anaerobic conditions. Depending on the amount of non-aqueous phase liquid (NAPL) present and the extent of hydrocarbon weathering (loss of soluble and volatile constituents), the oxidative treatment may be moot if constituents subsequently dissolve into anaerobic groundwater.**

Navy Response:

The Navy assumes that the comment is referring to pre-pilot study monitoring for oxidant demand, which was not performed. The area is small, persulfate exhibits low soil oxidant demand relative to other oxidants, the assumed oxidant demand was conservatively estimated and took into account the stoichiometric demand of the actual COC concentrations, and the oxidant demand can be monitored and dosing adjusted, if necessary, during the pilot study. Further, it is unlikely that residual NAPL is present, based on numerous rounds of water level/NAPL measurements conducted prior to planning the pilot study.

The following paragraphs have been added to the end of the Persulfate Injection in Groundwater section of Worksheet 14a: "Persulfate exhibits relatively low soil oxidant demand compared with other types of oxidants (e.g., permanganate). Considering the relatively small scale of the planned ISCO application the oxidant demand was assumed to be an average of 1 g persulfate for 1 kg of soil. The planned oxidant dosing took into account the stoichiometric demand of the actual COC concentrations in the groundwater. Monitoring following the first injection will help assess if the dosing is adequate. The oxidant demand decreases for areas having been treated before; thus, the demand of 1 g persulfate per kg of soil should be more than sufficient for re-applications of ISCO to maintain oxidative conditions in the aquifer. However, as stated above, monitoring will be conducted and the dosing adjusted as necessary based on the observations.

NAPL was historically present in monitoring wells MW-01 and MW-05 based on the RI Report for AOC E dated July 2008. During the implementation of a multi-phase extraction (MPE) pilot test from June 2002 to August 2002, the recoverable NAPL was removed, and only residual NAPL was measured. In March 2006, less than 0.1 foot of NAPL was measured in MW-01 and no measurable NAPL thickness was found in MW-05. The additional round of groundwater sampling conducted in July 2008 did not identify any NAPL in either MW-01 or MW-05. Given the relatively low VOC and SVOC concentrations (low ppb levels), it is unlikely that residual NAPL is still present. However, visual monitoring for a potential NAPL sheen has been included in the pilot study protocol. If any recoverable NAPL is present, a hand bailer will be used to remove it. Any minor residual NAPL, if present, should be addressed by the multiple ISCO injection events and/or the ORC sock treatment."

3. **In accordance with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* dated October 1988, a SAP should address health and safety issues in a site-specific health and safety plan (HASP). It does not appear that the Pilot Studies SAP references a HASP. Ensure that a HASP is included or referenced in the Pilot Studies SAP.**

Navy Response:

Worksheet #29 has been modified to include reference to the Vieques Master HASP and a project-specific HASP.

4. **The sampling rationale presented in the Pilot Studies SAP is incomplete. For example, Worksheet #10a states that five split spoon samples will be collected from two soil borings (SB-22 and SB-23). However, Worksheet #14a states that five continuous split spoon soil samples will be collected for the post-injection unsaturated soil sampling and that of those five samples, two confirmatory samples will be selected and sent for laboratory analysis. From the information provided, it is unclear what will be done with the other sample intervals or why five samples will address the study questions. Further, it is unclear why only two rounds of post-injection data are deemed sufficient to establish trends in groundwater and soil contaminant concentrations (i.e., soil heterogeneity alone may account for the differences in concentrations). Finally, the rationale for including the majority of analyses has not been provided (i.e., Worksheet #11 states that sulfate, nitrate, total organic carbon (TOC), soluble iron, soluble manganese, phospholipids fatty acids, and quantitative polymerase chain reaction for naphthalene dioxygenase and benzylsuccinate synthase in groundwater will also be analyzed). Revise the SAP to provide more detailed sample rationale for these items.**

Navy Response:

There does not appear to be a discrepancy between what is stated in Worksheet #10a and Worksheet #14a regarding the number of soil samples to be collected. Both worksheets indicate that in each of two soil borings, the two depth intervals (i.e., 16-20 ft bgs and 28-32 ft bgs) where the highest COC concentrations were detected in July 2008 will be re-sampled (plus one duplicate) following the nitrate injection. This equates to five total samples. The confusion may be due to the use of the term "continuous." The objective is simply to see whether the nitrate treatment results in contaminant (primarily naphthalene) concentration decreases in the soil of those two intervals. The pilot study memoranda (Attachments A and B of the SAP) indicate that leaching of contaminants is not likely a concern at the site for any constituent other than naphthalene and that even for naphthalene, existing soil concentrations would not likely leach to groundwater and cause exceedances of EPA's health advisory lifetime value. The nitrate treatment is being done simply as an added level of conservatism. It is important to note that the success of the pilot study will be based on the groundwater concentrations, not residual soil concentrations because measured or calculated soil concentrations are not necessarily accurate predictors of leaching to groundwater.

In addition, potential concentration differences due to soil heterogeneity is being addressed by analyzing all soil samples for all the groundwater COCs (plus benzene) even though the SPLP soil data from 2008 suggest only naphthalene is a potential leaching concern.

To clarify any apparent discrepancy in the number of soil samples to be collected and analyzed between the two worksheets, the language has been revised in Worksheets 10a and 14a. In addition, the soil sampling schedule has been revised in response to EPA Specific Comment #10. The revisions are as follows:

Worksheet 10a, Environmental Questions to be Answered by the Pilot Study, question 1, 4th paragraph has been replaced as follows: "A total of five split spoon soil samples will be collected from two soil borings (SB-22 and SB-23; see Figure 5) in general accordance with *Master Standard Operating Procedures, Protocols, and Plans* (CH2M HILL, July 2009). Two soil samples from each boring will be collected from the highest COC concentration depth intervals observed in July 2008 event for laboratory analysis: one from the unsaturated zone where injection occurred (16-20 ft bgs), and one from the smear zone below the injection interval (28-32 ft bgs). In addition, one field duplicate sample will be collected from one soil sampling depth in one soil boring. This equates to five total soil samples collected from the two soil boring locations. The samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2)."

Worksheet 14a, Soil and Groundwater Sampling (for Offsite Laboratory Analysis, 2nd and 3rd sentences have been replaced with: "A total of five split spoon soil samples will be collected from two soil borings (SB-22 and SB-23; see Figure 5) in general accordance with *Master Standard Operating Procedures, Protocols, and Plans* (CH2M HILL, July 2009). Two soil samples from each boring will be collected from the highest COC concentration depth intervals observed in July 2008 event for laboratory analysis: one from the unsaturated zone where injection occurred (16-20 ft bgs), and one from the smear zone below the injection interval (28-32 ft bgs). In addition, one field duplicate sample will be collected from one soil sampling depth in one soil boring. This equates to five total soil samples collected from the two soil boring locations. The samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2)."

A total of two rounds of post-injection groundwater sampling events have been proposed for evaluating the pilot study performance under the two ISCO injection scenario and three rounds of post-injection groundwater sampling for the three ISCO injection scenario. The sampling frequency is considered sufficient to evaluate performance of the pilot study based on the nature of the treatment technologies to

be applied. If additional sampling is warranted before making site-specific determinations, the specific requirements for additional groundwater sampling will be determined at the conclusion of the pilot study. This was specifically stated on pages 47 and 48 of the Draft SAP.

The rationale for including sulfate, nitrate, total organic carbon (TOC), soluble iron, soluble manganese, phospholipids fatty acids, and quantitative polymerase chain reaction for naphthalene dioxygenase and benzylsuccinate synthase in groundwater (listed in Worksheet 11) was stated in Worksheet #17, first paragraph in section AOC E. The paragraphs have been updated to read "Other groundwater geochemical parameters, including TOC, sulfate, nitrate, soluble iron, and soluble manganese will also be analyzed as performance indicator parameters to monitor ISCO and nitrate distribution and to help interpret the other data and evaluate the effectiveness of enhanced bioremediation. TOC will be monitored for evaluation of ISCO distribution and efficiency, as the oxidation process oxidizes organic matter and causes TOC to decrease. DO, nitrate, soluble iron, and soluble manganese, and sulfate concentrations will provide evidence of dominant electron acceptors in the groundwater, and help determine whether an aerobic environment is established and maintained for the EISB. Persulfate will be measured using field analytical tests to monitor oxidant demand distribution and ensure the oxidant is not being collected in the samples (i.e., sufficient time has elapsed to consume the persulfate). Pre-injection and post-injection field parameters (pH, temperature, specific conductivity, ORP, turbidity, and DO) will be measured to determine if aerobic aquifer conditions are established and maintained. Water table elevations and the potential presence of free product will also be measured pre- and post-injection to help ensure the applicability of the technology and determine the actual depth of smear zone soil sampling (i.e., to ensure it is above the water table).

Microbial parameters, comprising PLFA, and qPCR for abundance of microbes such as naphthalene dioxygenase (NAH) and benzylsuccinate synthase (BSSA), will be analyzed in one well (MW-01) as indicators for enhanced aerobic biodegradation of naphthalene and benzene. The analysis of PLFA and qPCR would provide insight into the biomass, biological community structure, physiological status, and the presence of select enzymes and microbes.

PLFA is a main component of the membrane (essentially the "skin") of microbes and provides a powerful tool for assessing microbial responses to changes in their environment. This type of analysis provides direct information for assessing and monitoring sites where bioremediation processes, including natural attenuation, are of interest. Analysis of the types and amount of PLFA provides a broad based understanding of the entire microbial community with information obtained in three key areas: viable biomass, community structure and metabolic activity. The parameters analyzed for PLFA have been included in Worksheet #15-9, specifically, including total biomass cell counts, firmicutes (Gram negative bacteria), proteobacteria, anaerobic metal reducers, actinomycetes, general Nsats, eukaryotes, slowed growth, and decreased permeability. Because groups of bacteria differ in their metabolic capabilities, determining which bacterial groups are present and their relative distributions within the community can provide information on what

metabolic processes are occurring at that location. This in turn can also provide another line of evidence on the subsurface conditions (i.e, oxidation/reduction status, aerobic/anaerobic etc.). Ratios for slowed growth and for decreased permeability of the cell membrane provide information on the "health" of the Gram negative community, that is, how this population is responding to the conditions present in the environment.

qPCR is a technique for identifying microbes directly from their DNA and for quantifying specific enzymes in a microbial population. It has the advantage over traditional culturing methods in sensitivity, accuracy, objectivity, and reproducibility. The quantitative analysis can be done on uncultured bacteria, thereby eliminating the need for a pure culture, special growth requirements, growth conditions, and preliminary testing. The presences of key enzymes that activate the initial step in a degradation pathway are considered strong evidence of microbial capabilities for biodegradation potential at a specific site. For aromatic hydrocarbon degradation in an anaerobic environment, benzyl succinate synthase (BSSA) is generally considered indicative of a microbial community's biodegradation potential. Following the ISCO/EISB treatment, it is anticipated that BSSA would decrease. On the other hand, increase in quantities of the aerobic functional gene naphthalene dioxygenase (NAH) would suggest an aerobic environment has been established following EISB treatment. The proposed qPCR ananlysis includes measuring the abundance of NAH and BSSA in groundwater in one of the monitoring well of AOC E during the pilot study period. The reference limits are also provided in Worksheet #15-9. The lab SOPs for Microbial Insights are also included in Attachment D of the SAP. Thus qPCR monitoring of the population shifting of BSSA and NAH during the ISCO/EISB treatment can be used to help assess the efficiency of the pilot study."

Similar revisions have also been made to Worksheet #17, first paragraph in section AOC I.

5. **The corrective action information presented in the SAP is insufficient. Revise the SAP to specify that EPA will be notified when significant corrective actions or changes occur. In addition, revise the SAP to provide the notification timing for the potential corrective actions identified in Worksheet #6 and #32.**

<u>Navy Response:</u>

Worksheet #6 row Implementation of pilot study injection and sampling activities; SAP changes in the field has had the Procedure cell modified to add "The EPA and PREQB RPMs will be notified within 24 hours of significant SAP changes in the field." The row Field corrective actions has had the Procedure cell modified to add "The EPA and PREQB RPMs will be notified within 24 hours of significant field corrective actions."

6. **The SAP does not discuss manual integrations. If manual integration is required, ensure that supporting information for manual integrations (i.e., chromatograms before and after manual integration as well as a brief explanation for the manual integration) will be included in the data package deliverables and evaluated during data validation.**

   Navy Response:

   Worksheet 29, new row added entitled "Manual Integration Documentation." The Where Maintained cell is "Hardcopy in the full data package. Archived at project closeout."

7. **It is unclear what percentage of the data will go under full validation. For example, Worksheet #34 states that all received data packages will be verified externally by a third party validator. However, Worksheets #11 and #35 state that 10% of the raw data will be reviewed to confirm laboratory calculations. Revise the SAP to indicate what percent of data will be validated, at what level, and how samples will be chosen for each validation level.**

   Navy Response:

   As indicated by Worksheet #34, all applicable data packages will be verified externally by a third-party validator. As detailed by Worksheet #36, VOC, SVOC, SPLPV, and SPLPS are the only analysis groups that will undergo third-party validation. The Description column of two cells on Worksheet 34, rows Case Narrative and Laboratory Data, have been amended to clarify that all (100% of) VOC, SVOC, SPLPV, and SPLPS data will undergo third-party validation. The remaining fractions (MICRO, FMETAL, and WCHEM) will not undergo third-party validation and will instead undergo an internal evaluation as detailed by Worksheet 36. Of the data that are third-party validated, the data validator will choose 10% of data points to recalculate from the raw data in order to verify calculations.

8. **The historical analytical results provided in the SAP are insufficiently detailed. For example, reporting limits have not been included in Tables ES-1 and ES-2. Without the reporting limits it is difficult to evaluate the data (i.e., results for naphthalene show results at 4.8 µg/L as being detected with no qualifiers and results at 5.4 µg/L as not detected). Further, historical results to be used as the soil baseline concentrations are not presented. Finally, it is unclear if the soil and groundwater data have been validated, or if validation qualifiers are included with the results. Revise the SAP to provide reporting limits, soil baseline results including if the results are dry weight corrected, and indicate what if any validation qualifiers should be associated with the results. If the historical samples have not been validated, the SAP should also be revised to indicate that fact.**

Navy Response:

The SAP already contains the information requested and has been provided in a manner consistent with Vieques reports. Historical baseline soil concentration results were provided in Attachment B and C of the SAP. A new table, Table ES-3, has been created to provide a summary of baseline soil concentration data sampled in July 2008 to make the data more readily accessible. Table ES-3 has been created to present the range of concentrations of targeted VOCs and SVOCs, TPH, SPLP VOCs and SVOCs, and SPLP TPH, pH, and TOC concentrations from two soil samples (SB20 and SB21) collected in July 2008 from the highest COC concentration depth intervals observed: one from the unsaturated zone (16-20 ft bgs), and one from the smear zone (28-32 ft bgs). These data will serve as the basis for comparison to confirmation soil samples (SB-22 and SB-23) after the proposed DBB treatment. QLs are reported only for nondetect data as the result associated with a U-qualifier. To specifically address the 4.8 v. 5.4, these data points were collected eight years apart and QLs have improved. All data have been validated. Only validation qualifiers have been provided. Soil results are always reported on a dry-weight basis.

Specific Comments:

1. **SAP Worksheet #10a – AOC E Problem Definition, Page 29:**
   The first paragraph on Page 29 references the floating product observed on the water table in the past and the fluctuation of the groundwater surface that has likely created a "smear zone". From the February 26, 2009 Telephone Conversation Record discussed in SAP Worksheet #9b – Project Scoping Session Participants Sheet, Page 26, the consensus agreement stipulated that visual monitoring be performed for potentially re-occurring sheen due to non-aqueous phase liquid (NAPL) that was present in the past and the relatively high-magnitude groundwater fluctuations. Discuss the approach that will be taken in the event NAPL is encountered and the impact it may have on the effectiveness of the selected treatment methodologies.

   Navy Response:

   Please refer to the response to General Comment #2 regarding NAPL. Although it is unlikely that NAPL exists at AOC E due to the historical NAPL recovery during a pilot MPE program and from the last three years of NAPL thickness measurements, if a sheen is observed, the ISCO injections will likely oxidized it. If recoverable NAPL is observed, hand bailer will be used to remove any recoverable NAPL, then the necessity of using another round of ISCO to remove residual NAPL will be evaluated at that time. This information has been added to Environmental Question 2 of Worksheet #10a and to the Field Parameter Monitoring and Groundwater Gauging (Onsite Measurement) section of Worksheet #14a.

2. **Worksheet #10a- AOC E Problem Definition, Page 29:**
   In the Summary of Baseline Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ER), it states that benzene, naphthalene, and MTBE exceeded the pilot study preliminary remediation goals (PRGs) in July 2008 for Area of Concern (AOC) E. However, Table ES-1: COC Concentration Trends, AOC E, does not include benzene. Revise the SAP to clarify this apparent discrepancy. If benzene was analyzed in AOC E, revise Table ES-1 to include the associated analytical results.

   Navy Response:

   Table ES-1 has been revised to include the benzene concentration trend data.

3. **Worksheet #10a- AOC E Problem Definition, Page 31:**
   This section indicates that the July 2008 soil sample results (SB-20 and SB-21) will be used as the baseline. However, from the information presented, it is not clear if the proposed soil samples will produce data that can be compared to the 2008 results. Since only limited soil sampling is proposed, the SAP should clearly document why the proposed data and historic data should be comparable. Revise the SAP to clarify if the July 2008 samples were analyzed by the same laboratory that will analyze the new soil samples. In addition, revise the SAP clarify if the proposed sample collection, preparation and analytical procedures were also used with the 2008 soil

samples. If any of these have changed, it is suggested that new baseline samples be collected using the SAP procedures.

Navy Response:

The proposed sampling and analytical protocol between the two events is comparable. The analytical protocol was chosen to address the data needs for this project. The laboratory has changed (CompuChem in 2008 v. Mitkem). The analytical methods have changed (EPA CLP SOM01.2 and EPA CLP ILM05.4 v. SW-846 8260C, 8270D, and 6010B). There are no comparability issues between the EPA CLP methods and corresponding SW-846 methods. Sample collection techniques will not change. The new selected laboratory must be appropriate for the current data needs and that fact is evidenced by the UFP-SAP workplan. New baseline samples will not be recollected.

It is also important to retain focus on the fact that the success of the pilot study will be based on the groundwater concentrations, not residual soil concentrations because measured or calculated soil concentrations are not necessarily accurate predictors of leaching to groundwater. The pilot study memoranda (Attachments A and B of the SAP) indicate that leaching of contaminants is not likely a concern at the site for any constituent other than naphthalene and that even for naphthalene, existing soil concentrations would not likely leach to groundwater and cause exceedances of EPA's health advisory lifetime value. The nitrate treatment is being done simply as an added level of conservatism.

4. **Worksheet #11 – Project Quality Objectives/Systematic Planning Process Statements, Page 44:**
This section states that the maximum naphthalene concentration measured in July 2008 at MW-05 was 33 µg/L. However, Table ES-1 shows that the maximum concentration is 35 µg/L. If the maximum concentration is 35 µg/L, the dilution factor changes to approximately 2.1, and the associated soil PAL presented in Table 2 changes from 11.5 µg/L to 10.5 µg/L. Revise the SAP to address this discrepancy.

Navy Response:

Worksheet #11 has been corrected to show the maximum naphthalene concentration as 35 µg/L and the associated dilution factor as 2.1, based on the concentration of 35 µg/L in July 2008 at MW-05. Worksheets 15-3 and 15-4 tabulated PALs have been adjusted to reflect the dilution factor of 2.1, and footnote 1 of each of these worksheets has been revised to reflect the adjusted dilution factor. Specifically, the following have been revised in Worksheet 11:

Worksheet 11, question 2, last sentence before Table 2 has been revised to say "Under a conservative assumption, a dilution factor of 2.1 (i.e., 75 µg/L ÷ 35 µg/L = 2.1) would be considered conservative and applicable for determination of the following soil PALs for evaluation of soil-to-groundwater leaching pathway." Worksheet 11 Table 2 has been revised to show the following PALs based on the 2.1 dilution factor: Benzene 10.5 µg/L, 1,2-dichloroethane 10.5 µg/L, 2-

Methylnaphthalene 315 µg/L, MTBE 252 µg/L, Naphthalene 2.94 µg/L, Xylenes, total 21,000 µg/L. The note below Table 2 has been revised to say "…an acceptable SPLP value would be 210 µg/L." The source of PALs column in Table 2 has been revised to read: "Groundwater PRG adjusted by dilution factor of 2.1."

5. **Worksheet #12 - Measurement Performance Criteria, Pages 51-53, 56-58:**
The tables for FMETAL, MICRO, and WCHEM analyses only include temperature blanks. Revise the SAP to clarify why other QC samples (e.g., field duplicates, matrix spike/matrix spike duplicates [MS/MSD]) are not included for these analyses.

Navy Response:

The measurement of efficacy of the pilot study is contaminant concentration reductions in groundwater and, therefore, these contaminant analyses warrant a higher level of quality assurance than those of the analyses listed in the comment, which are used solely to help interpret the aquifer conditions supporting contaminant degradation. Ultimately, the particular value from any one of these analyses is not critical to evaluating the success of the pilot study; an indication of conditions, based on the multiple supporting analyses, is sufficient. Therefore, these analytes do not warrant the same level of QC samples as the samples being analyzed for COCs. A footnote has been added to Worksheets 12-3, 12-4, 12-5, 12-8, 12-9, and 12-10 to state that "the particular value from these analyses is not critical to evaluating the success of the pilot study and thus does not warrant the same level of QC samples as the samples being analyzed for COCs."

6. **Worksheet #13 – Secondary Data Criteria and Limitations Table, Page 59:**
This table does not indicate if there are limitations on the July 2008 soil sample results. Since these results will be used to establish baseline soil concentrations, this information should be presented in the table. Revise the table to include any limitations or QC issues related to the July 2008 data.

Navy Response:

There are no limitations on the July, 2008 soil sample data for their intended use as baseline. The data are comparable to the data collection that is described by this UFP-SAP. Worksheet 13, last row in AOC E section, Limitations on Data Use column, cell has been amended with the statement "Soil data have no QC issues or limitations to their use as baseline soil concentrations."

7. **SAP Worksheet #14a – Summary of Project Tasks for AOC E, Nitrate Injection in Unsaturated Zone Soil, Page 63:**
The first paragraph, Nitrate DPT Injection, states that the seven temporary injection points (IP-1 through IP-7) will be hydraulically pushed to the targeted treatment depth of 26 feet below ground surface (bgs) and will be fitted with an injection screen of one- to five-foot length. It is unclear whether the nitrate solution will reach the full

boring interval or simply the base of the boring and how the injected nitrate solution will then be delivered to the entire targeted treatment zone of 16 to 26 feet bgs. In addition, the paragraph states that if the required quantity of nitrate solution can be delivered through the single injection event, then the borehole with be grouted. The second paragraph, Nitrate Gravity Trickle Feeding Via Temporary Injection Points (Contingency), states that if the required quantity of nitrate solution cannot be injected in a single "slug" due to low permeability subsurface conditions (which are expected) then the boreholes will be converted to temporary injection points by installing a one-inch diameter PVC riser with a 10-foot screen. Given the uncertainty of the effectiveness of the single slug injection process, the low permeability of the formation, and the inability of performing additional injections, if necessary, consideration should be given to installing the seven injection points using the PVC riser and 10-foot screen lengths as a first step.

Navy Response:

Worksheet 14a Nitrate Injection in Unsaturated Zone Soil, first paragraph will be appended with the following: "At each location, an initial attempt will be made using the above method. If the injection rate is so slow that this method is not efficient, the borehole will be converted to a temporary injection point well as described below under Nitrate Gravity Trickle Feeding Via Temporary Injection Points (Contingency). "

Worksheet 14a, Nitrate DPT Injection, 4th through 6th sentences will be replaced with "The GeoProbe will hydraulically push a probe, fitted with an injection screen, of an assumed length of 5 feet, to a depth of 5 feet into the target zone of 16-26 feet (i.e. to 21 feet). The probe tool will then be drawn back to expose the 5 foot injection screen to the formation from 16 to 21 feet bgs. Half the nitrate solution will be injected as a "slug" (if possible) followed by 20 gallons of water chaser to flush the nitrate from the borehole into the formation. The probe will then be pushed 5 feet further to 26 feet bgs, and the tool pulled back to expose the screen to the formation from 21 to 26 feet bgs. The injection process will be repeated in this interval. If the probe tool available has a screen length shorter than 5 feet, the zones exposed to the screen and slugs of nitrate injected, will be adjusted so that the nitrate is still injected throughout the full 16 to 26 foot length."

8. **SAP Worksheet #14a – Summary of Project Tasks for AOC E, Persulfate Injection in Groundwater (ISCO), Page 65:**
The second paragraph on Page 65, Oxidant Demand, describes the amount of persulfate required for an approximately 50-foot by 25-foot treatment area. The data or assumptions used to determine the lateral and vertical extent of the treatment area are not provided in the Pilot Studies SAP. Provide information on how the treatment area was estimated.

Navy Response:

Worksheet 14a, Persulfate Injection in Groundwater (ISCO), 4th paragraph, the end of the Oxidant Demand paragraph will be amended with the following: "The lateral

and vertical extent of the treatment area is based on the COC concentrations in monitoring wells MW-01 and MW-05. Analytical results from these wells exceeded their respective PRGs during the additional groundwater sampling performed in July 2008 and historical groundwater sampling data reported in the RI report dated July 2008."

9. **SAP Worksheet #14a – Summary of Project Tasks for AOC E, Installation of ORC Socks (EISB), Page 66:**
Oxygen Release Compound (ORC) socks are to be installed into the four existing monitoring wells that will be treated with in-situ chemical oxidation (ISCO), including MW-04 which is located side-gradient or down-gradient of the likely release, but has not had contaminant concentrations greater than the PRGs. Explain why MW-04 is proposed for inclusion in the EISB implementation.

Navy Response:

Although no exceedances of regulatory criteria were found in MW-04 during the July 2008 event, MTBE was measured at a concentration of 234 µg/L in 2004 at MW-04. MTBE concentration measured at MW-04 in July 2008 (110 µg/L) was slightly lower than the PRG of 120 µg/L. MW-04 was therefore included in the EISB approach to account for the potential for MTBE fluctuations in MW-04. Furthermore, MW-04 is located downgradient of the likely release, so including MW-04 in the EISB implementation would address any potential downgradient migration.

10. **SAP Worksheet #14a – Summary of Project Tasks for AOC E, Soil and Groundwater Sampling (for Offsite Laboratory Analysis), Page 66:**
The first paragraph of this section states that post-injection unsaturated zone soil sampling will be collected at month 26 or month 29. It appears that post-injection sampling and analysis of unsaturated zone soils should occur during an earlier sampling event to evaluate the effectiveness of this treatment, especially with respect to the presence of potential NAPL. Consideration should be given to conducting post-injection sampling sooner than months 26 or 29.

Navy Response:

Worksheet 14a, Soil and Groundwater Sampling (for Offsite Laboratory Analysis), first sentence will be changed to "Post-injection unsaturated zone soil samples will be collected approximately midway through the groundwater pilot study (see Worksheets 16a-1 and 16a-2). If the SPLP analytical results of this soil sampling event are above the SPLP PALs (see Worksheet #11), a second round of soil samples from the same intervals at immediately adjacent locations will be collected at the end of the groundwater pilot study (see Worksheets 16a-1 and 16a-2)." Worksheets 16a-1 and 16a-2, 18a-1 and 18a-2, 20, and 30 have been revised accordingly.

11. **<u>SAP Worksheet #14b – Summary of Project Tasks for AOC I, Persulfate Injection in Groundwater (ISCO), Page 69:</u>**
The third paragraph of this section, Oxidant Demand, describes the amount of persulfate required for an approximately 25-foot by 25-foot treatment area and a 10-foot treatment thickness. Given the depth of the screened intervals from 24 to 43 feet bgs and the range of depths to groundwater (17 to 25 feet bgs), the vertical extent of the treatment zone appears to be greater than the estimated treatment thickness. Provide the data or assumptions used to determine the size and thickness of the treatment area. Ensure the treatment zone includes sufficient area to achieve the remediation goals.

<u>Navy Response:</u>

The proposed pilot study at AOC I was designed to use the existing monitoring wells within the extent of groundwater impact area as injection wells. During the project scoping activities, telephone meetings and conversations (refer to SAP Worksheet #9a and #9b on Page 23 and 26), the group reached consensus that the existing monitoring wells would be used as injection network due to the relatively small area of contamination, high cost to install separate injection wells, and close proximity of new injection wells to the existing monitoring wells. The existing monitoring wells have 10-foot-screen interval at various depths. The oxidant demand is calculated for a total treatment zone thickness of 20 feet instead of 10 feet, to account for the treatment zone defined by various screen intervals.

12. **<u>Worksheets #15-1 and 15-2, Reference Limits and Evaluation Tables, Pages 73 and 74:</u>**
These tables do not indicate if the action limits and quantitation limits are dry weight corrected. Revise the tables to indicate this in a footnote, or explain why wet weight results will be used.

<u>Navy Response:</u>

Action limits assume that data are reported on a dry-weight basis. Results are always reported on a dry-weight basis. Worksheet 15-1, footnote 1 has been amended with the following statement "All analytical data reported on a dry weight basis."

13. **<u>Worksheet #16a-1 – AOC E Project Schedule/Timeline Table (2 ISCO Injection Events):</u>**
This timetable does not include the date that pre-injection sampling will occur. Revise the timetable to include this.

<u>Navy Response:</u>

Worksheet #16-1a already shows the pre-injection sampling will occur in Month 1.

14. **Worksheet #16b – AOC I Project Schedule/Timeline Table:**
This timetable does not include the date that pre-injection sampling will occur. Revise the timetable to include this.

Navy Response:

Worksheet #16b already shows the pre-injection sampling will occur in Month 1.

15. **SAP Worksheet #21 – Project Sampling SOP Reference Table:**
It does not appear that a project standard operating procedure (SOP) has been developed for the installation of the temporary injection points. Develop and include an injection point SOP as an Attachment to the SAP.

Navy Response:

An injection point SOP has been included with the SAP as Attachment H.

16. **Worksheet #22 – Field Equipment Calibration, Maintenance, Testing, and Inspection Table, Pages 99- 100:**
This table does not include the maintenance activity and/or testing/ inspection activity for all the field equipment. Revise the table to include the maintenance and testing/inspection activities for all field equipment.

Navy Response:

The Maintenance Activity and Testing/Inspection Activity information for the YSI multi-meter has been copied into the Maintenance Activity and Testing/ Inspection Activity cells for YSI pH probe, YSI Specific conductance probe, Hach Turbidity Meter, and YSI Dissolved oxygen and Temperature Probes.

17. **Worksheet #27 – Sample Custody Requirements Table, Pages 113:**
This section does not include an example of sample numbering system to be used. Revise the worksheet to include an example of the sample numbering system.

Navy Response:

The sampling numbering system has been attached to the SAP as Attachment I.

18. **Worksheet #29 – Project Documents and Records Table, Page 131:**
This table does not specify the length of time documents will be stored, nor does it provide the address or contact information for the document storage location. Revise the SAP to provide this information.

Navy Response:

The contractual requirements regarding document retention between CH2M HILL and the Navy are private and are not necessary for this SAP. All document retention

and storage is done in accordance with contractual agreements between CH2M HIL and the Navy.

19. **<u>Worksheet #31 – Planned Project Assessments Table, Page 135:</u>**
This table does not include laboratory audits. Clarify if any laboratory audits will be conducted.

<u>Navy Response:</u>

A footnote has been added to Worksheet 31 stating "Note: Analytical laboratory audits by the contractor are not project-specific, but are done on a Navy CLEAN program-wide basis. However, the laboratory is subject to audits due to NFESC evaluation and will also be subject to audits due to DoD ELAP acceptance during the project timeframe."

20. **<u>Worksheet #37: Usability Assessment, Page 87:</u>**
This section does not provide a completeness goal for the field and laboratory. In addition, it is unclear if completeness will be calculated on a per sample or per analyte basis. Revise the SAP to provide this information. If completeness will be calculated on a per sample basis, revise the SAP to indicate when a sample will be considered as rejected (e.g., if one compound is rejected, if 5 results are rejected, etc.).

<u>Navy Response:</u>

Completeness is defined within Worksheet 37, footnote 1 as: "Completeness is defined as the percentage of measurements that are judged to be available compared to the total number of measurements made. The objective of the overall completeness goal for this project is set at 95% available data. This goal is inclusive of both field and laboratory analytical data." To clarify, the first sentence of the footnote has been revised to read: "Completeness is defined as the percentage of analyte results that are judged to be available (i.e. not rejected) compared to the total number of results generated." The following has been added to Worksheet 37, footnote 1 "Results may be considered rejected, based on laboratory QA/QC non-conformances or failures. In rare and extreme circumstances, however, depending on intent of data usage these results may still be useable for project decisions. If rejected data are proposed for use, the rationale supporting their use will be included in the associated report provided for regulatory review. If the data are considered not usable, they are not considered in the available data set and therefore do not contribute to the completeness goal. Patterns of rejection are examined by sample and also by analyte as part of the data quality evaluation."

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Final Responses to
PREQB June 2009 Comments

Draft In-Situ Remediation Pilot Studies (AOC E and AOC I Sites) Sampling and Analysis Plan,
Former Naval Ammunition Support Detachment,
Vieques, Puerto Rico, September 2009

General Comments:

The following discrepancies between the approach discussed in the Pilot Study Technical Memorandum for AOC E (December 2008) and this Sampling and Analysis Plan (SAP) were identified. Please clarify why the identified changes were made.

i) The Technical Memorandum stated that the confirmatory soil samples would be analyzed for VOCs, SVOCs, TPH, and nitrate. However, the SAP calls for these soil samples to be analyzed for select VOCs, select SVOCs, SPLP VOCs, SPLP SVOCs, TOC, pH and nitrate. It appears that TPH has been eliminated from the program.

Navy Response:

There are several deviations in the pilot study approach presented in this (draft) SAP prepared in June 2009 versus the Technical Memorandum *Proposed Pilot Study of In-situ Remediation at Vieques AOC E,* dated December 19 2008. This is because the Technical Memorandum was conceptual in nature, whereas the approach presented in this SAP was developed using a systematic process and, therefore, supersedes the Technical memorandum approach. This was explicitly stated on page 30 of the Draft SAP.

As stated in the HHRA included in the Final Remedial Investigation Report (CH2M HILL, 2008), no unacceptable risks were identified from potential exposure to soil contaminants at AOC E. The HHRA also identified only five COCs in groundwater (1,2-DCA; 2-methylnaphthalene, MTBE, naphthalene, and xylenes). A sixth contaminant of interest (benzene) was identified in the pilot study memorandum (Attachment B of this SAP) due to a single detection above its MCL. The Synthetic Precipitation Leaching Procedure (SPLP) analysis of soil samples collected in July 2008 indicated that naphthalene is the only COC whose concentration in soil may leach from unsaturated soil into groundwater and result in a PRG exceedance. However, even for naphthalene, existing soil concentrations would not likely leach to groundwater and cause exceedances of EPA's health advisory lifetime value. Further, historical TPH groundwater concentrations were either non-detect or two orders of magnitude lower than the PREQB's Land Pollution Control Corrective Action Level of 50 mg/L, showing that TPH leaching from soil to groundwater is not likely a concern at this site. Based on the above, the particular analyses proposed in the SAP for the soil samples

are appropriate and appropriately conservative. However, because AOC E is a former UST site, TPH (diesel-range, gas-range, and oil-range) will be included for both soil and groundwater analysis to evaluate the concentration reduction compared to the baseline data. PREQB's Land Pollution Control Corrective Action Levels of 100 mg/kg for TPH in soil and 50 mg/L for TPH in groundwater are not PRGs, but will be used as PALs for quantitative analysis of this parameter. Other parameters, including TOC, pH, and nitrate were added to the list of parameters to assist the performance evaluation of the nitrate injection bioremediation. The rationale for selecting the above parameters for soil analysis has been discussed in detail on pages 34 and 88 of the Draft SAP.

In Worksheet #10a, Environmental Questions to be Answered by the Pilot Study, Question 1, 5th paragraph, the first sentence has been modified to say "The samples will be analyzed for VOCs, (benzene, 1,2-dichloroethane, MTBE, total xylenes), SVOCs (2-methylnaphthalene and naphthalene), SPLP VOCs and SVOCs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene), TPH (ranges GRO, DRO, and ORO), TOC, pH, and nitrate."

In Worksheet 10a, Environmental Questions to be Answered by the Pilot Study, Question 2, 1st paragraph, the sixth sentence has been modified to say "The pre-injection concentrations of COCs (benzene, 1,2-dichloroethane, MTBE, total xylenes, 2-methylnaphthalene and naphthalene) and TPH (ranges GRO, DRO, and ORO) collected during month 1 will be used as the baseline data."

In Worksheet #11, Question 2, the first sentence below Table 2 has been modified to say "Other soil and/or groundwater analyses pertinent to pilot studies at AOC I and/or AOC E consist of VOCs, SVOCs, and TPH (ranges GRO, DRO and ORO) in soil; and TPH (ranges GRO, DRO, and ORO), sulfate, nitrate, TOC . . . in groundwater, all collectively referred to as indicator parameters."

In Worksheet #14a, Soil and Groundwater Sampling (for Offsite Analysis), first paragraph, last sentence has been changed to ". . . pH, TPH (ranges GRO, DRO, and ORO), and nitrate."

In Worksheet #14a, Soil and Groundwater Sampling (for Offsite Analysis), second paragraph, third sentence from last has been changed to ". . . , as well as TPH (ranges GRO, DRO, and ORO) and other geochemical parameters."

Worksheet #15-11 Reference Limits and Evaluation Table has been created for TPH in subsurface soil, and Worksheet #15-12 Reference Limits and Evaluation Table has been created for TPH in groundwater. For Worksheet #15-11, the QL/MDLs are TPH-GRO (2.5 mg/kg and 1 mg/kg), TPH-DRO (9 mg/kg and 1.4 mg/kg) and TPH-ORO (12 mg/kg and 2.5 mg/kg). PALs for each are 100 mg/kg (i.e. the PREQB Land Pollution Control Corrective QAction Level). For Worksheet #15-12, the QL/MDLs are TPH-GRO (0.1 mg/L and 0.0034 mg/L), TPH-DRO (0.28 mg/L and 0.042 mg/L) and TPH-

ORO (0.35 mg/L and 0.088 mg/L). The PALs for each are 50 mg/L (i.e., the PREQB Land Pollution Control Corrective Action Level).

Worksheet #17, AOC E, 2nd paragraph, last sentence has been changed to "Soil analyses will comprise the COCs and TPH in soil for comparison to baseline concentrations to evaluate percent reduction, and COCs in leachate (i.e. SPLP) to evaluate whether the post-injection COC concentrations in soil pose a potential leaching concern."

Worksheet #17, AOC E, 1st paragraph, 2nd sentence will be changed to "Due to the potential for fluctuations in groundwater concentrations and elevations, all of the COCs identified in the HHRA plus benzene (exceedance of MCL observed in July 2008) and non-COC TPH (ranges GRO, DRO, and ORO)."

Worksheets #18a-1 and18a-2 have been revised to include TPH-DRO, GRO, and ORO at each location.

Worksheet #19 has been updated to include TPH-GRO and TPH (DRO and ORO) in SB and TPH-GRO and TPH (DRO and ORO) in GW. TPH-GRO in soil will be collected in the same manner as VOCs.

Worksheet #20 has been updated to include TPH-GRO, DRO, and ORO.

Worksheet #23 has been updated to include the analytical laboratory SOPs for TPH. No SOP modifications are needed.

Worksheet #24 has been updated to include the calibration for the GC for TPH.

Worksheet #25 has been updated to include the GC for TPH.

Worksheet #28-11 (Laboratory QC Samples Table, TPH in SB) and Worksheet #28-12 (Laboratory QC Samples Table, TPH in GW) have been added to the SAP.

Worksheet #30 has been updated to include TPH in GW and SB. Mitkem will perform the analysis using a standard 28 calendar day TAT.

Worksheet #36 has been updated to include TPH. TPH will be third-party validated. There are no Region II Data Validation SOPs for TPH. The text says "Analytical methods and laboratory SOPs, as presented in this UFP-SAP, will be used to evaluate compliance against QA/QC criteria. Data may be qualified if a QA/QC exceedance has occurred. Data qualifiers will be those presented in USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA, Rev. Final, October, 1999)."

ii) The Technical Memorandum called for groundwater sampling 3 months after the first ISCO treatment for COCs (benzene, naphthalene, MTBE), sulfate, nitrate, soluble iron, and soluble manganese. According to the SAP Worksheet #16, the Project Schedule, only field parameters and persulfate will be analyzed for 3 months after first ISCO treatment.

Navy Response:

As stated in response to General Comment I i), the SAP supersedes the Technical Memorandum because it employed a systematic approach versus the conceptual approach used for the pilot study memorandum. As concurred upon during the ERP Technical Subcommittee conference call on November 12, 2009, additional sampling prior to the second injection is not warranted. The objective of the injections is to create oxidizing conditions in the aquifer that will promote contaminant degradation. The exact timing of the second injection is not critical and, therefore, sampling between the first and second event is not cost-effective. Therefore, the second injection will go as originally planned, and a sampling event is scheduled (see Worksheet 16a-1 and 16a-2) after the second injection to determine the effectiveness of the injections and to see if a third injection is needed. During the Pilot Study SAP development process, the Navy, USEPA, and PREQB documented that "The approach should maximize the confidence that the monitoring data being collected are truly representative of the aquifer conditions, not of the injected material. For example, Propose a time interval between injection and sampling that is considered sufficient for the injected material to dissipate." (see Worksheet #9b). To comply with this, the post-injection groundwater sampling event was established at 7 months instead of 3 months after the last ISCO injection, to allow sufficient time for the injectate to dissipate. The longer sampling interval will allow more oxidation and equilibration time to better assess the potential of rebound. Therefore, the second groundwater sampling event will take place 7 months after the second ISCO injection to determine the need for a third ISCO injection (as discussed below).

iii) The Technical Memorandum called for groundwater sampling 3 months after the second ISCO injection for COCs (benzene, naphthalene, MTBE), sulfate, nitrate, soluble iron, soluble manganese as well as field parameters. According to the SAP, Worksheet #16, no sampling is being performed 3 months after the second ISCO injection; instead this is being done 7 months after the second ISCO injection (unless a third ISCO injection is being performed and then field parameters only being measured 3 months after the second ISCO injection). Also, it is unclear how it will be determined if a third ISCO treatment is needed without sampling groundwater for the COCs and comparing the concentrations to threshold values on page 34 of Worksheet #10.

Navy Response:

Refer to the response to General Comment I ii) for the rationale behind conducting the groundwater sampling event 7 months after injection.

However, the comment on the groundwater sampling to determine whether a third ISCO treatment is needed is acknowledged. For the contingency schedule (Worksheet #16a-2), the 2-injection schedule has now been used as the basis (i.e., showing post-injection sampling 7 months after the second injection). If, based on these results, a third ISCO injection is deemed warranted, it will take place approximately 2 to 3 months after the sample collection (to allow for sample analysis and evaluation). The remainder of the schedule in Worksheet #16a-2 has been adjusted to account for the third injection taking place approximately in month 13.

Worksheet #10a, Environmental Questions to be Answered by the Pilot Study, Question 3, to the end of the paragraph has been added the sentence "Analytical results from the groundwater sampling event 7 months after the second injection will be used to make the determination if a third ISCO treatment is needed by comparing these analytical results to the threshold COC concentrations."

To Worksheet #14a, Soil and Groundwater Sampling (for offsite Laboratory Analysis), second paragraph, the second sentence has been changed to "Two rounds of post-injection performance groundwater sampling will be conducted for the two ISCO injection scenario as listed in the schedule in Worksheet #16a-1. Three rounds of post-injection performance groundwater sampling will be conducted for the three ISCO injection scenario as listed in the schedule in Worksheet #16a-2."

Worksheet 16a-2 has been changed to reflect the above changes, and the Notes have been changed to reflect the month 11 groundwater sampling event.

Worksheet 18a-2 has been changed in the number of samples column for MWs 1, 4, and 5 to reflect 4 samples (month 1, 11, 20, and 35). For MW 3 the number of samples has been changed to 8 (4 duplicates, month 1, 11, 20, and 31).

Worksheet 20 has been revised to reflect the additional groundwater sampling event.

iv) The Technical Memorandum called for groundwater sampling 3 months after the third ISCO treatment for COCs (benzene, naphthalene, MTBE), sulfate, nitrate, soluble iron, soluble manganese as well as field parameters. According to the SAP, Worksheet #16, no sampling is being performed 3 months after the third ISCO treatment; instead this is being done 7 months after the third ISCO injection.

Navy Response:

Refer to responses to General Comments I i), I ii) and I iii). Please see revised Worksheet #16b.

v) The Technical Memorandum called for deployment of socks 7 months after the last ISCO injection. According to Worksheet #16, deployment of the socks will occur 11 months after the last ISCO injection.

Navy Response:

The exact timing of the sock installation is not critical. The sock placement is to take place concurrently with a groundwater monitoring event for efficiency.

vi) The Technical Memorandum called for waiting 3 months after the socks are removed before sampling. According to the SAP, Worksheet #10a and Worksheet #16, this waiting period will be 2 months.

Navy Response:

As stated in response to General Comment I i), the SAP supersedes the Technical Memorandum because of a more systematic approach used. Two to 3 months of equilibrium time after sock removal is considered sufficient for assessing treatment, so sampling after 2 months was proposed in the SAP. The original Technical Memorandum stated "approximately 3 months after sock removal" and Exhibit 4 of the Technical Memorandum showed groundwater sampling 2 months after sock removal.

vii) The Technical Memorandum called for analyzing groundwater three months after the socks were removed for VOCs, SVOCs, and TPH. It appears that TPH has been eliminated from the program.

Navy Response:

Please refer to responses to General Comment I i).

Page-Specific Comments:

1. **Page 5, Worksheet #3: Distribution List:**
Please include the following people on the Distribution List for the Sampling and Analysis Plan (SAP) as they are listed on either Worksheet #4 (Project Personnel Sign-off Sheet) or Worksheet #5 (Project Organizational Chart):

   a) **Navy QA Officer, Sherri Eng**

   b) **CH2M Hill Quality Assurance Officer, Paul Favara**

   c) **CH2M Hill Program Chemist, Anita Dodson**

   d) **CH2M Hill Health and Safety Officer, Mark Orman**

   Navy Response:

   These personnel are involved in the SAP development and/or review process and do not receive a copy of the final SAP. Therefore, they are not added to Worksheet #3.

   Page 45, Worksheet #11: Project Quality Objectives/Systematic Planning Process Statements:
As part of the response to question #2, the text states that the quantitation limits (QLs) are greater than the project action limits (PALS) for SPLP naphthalene in subsurface soil, naphthalene in groundwater, and bis(2-ethylhexyl)phthalate in groundwater. The text states that these exceedances are acceptable since the method detection limits (MDLs) for these compounds are below the respective PALs and any detected concentrations would therefore be reported as estimated values. However, for this investigation which focuses on a small number of contaminants of concern (COCs), every effort must be made to have QLs lower than the PALs. If these compounds are not detected, the QLs will be above the preliminary remedial goals (PRGs) and decisions will not be able to be made with a high degree of accuracy, MDLs should not be relied upon to achieve project objectives as these values are statistically derived. The accuracy of MDLs is verified by the laboratory analysis; however, the accuracy of QLs is verified by the analysis of standards at the QL. As per comments #5 and 6 below, it is appropriate to use selective ion monitoring (SIM) analysis to ensure all QLs will meet the PALs. Revise this worksheet accordingly.

   Navy Response:

   For SVOCs in groundwater and SPLP leachate, the laboratory will modify the method to include an additional calibration standard that is less than the PAL. As a result, all QLs for these analysis groups will be less than the respective PALs.

2. **<u>Page 75, Worksheet #15-3: Reference Limits and Evaluation Table (SPLP VOCs):</u> Please revise the PALs column to include the values listed in Table 2 on page 44 of Worksheet #11.**

<u>Navy Response:</u>

Worksheet #15-3: Reference limits and evaluation table (SPLP VOCs) PALs column has been revised to include the values listed in Table 2, corrected for a dilution factor of 2.1 as follows: MTBE 252 µg/L, benzene 10.5 µg/L, 1,2-dichloroethane 10.5 µg/L, xylenes, total 21,000 µg/L,

3. **<u>Page 76. Worksheet #15-4: Reference Limits and Evaluation Table (SPLP SVOCs):</u>**
   a. **Please revise the PALs column to include the values listed in Table 2 on page 44 of Worksheet #11.**

<u>Navy Response:</u>

Worksheet #15-4: Reference limits and evaluation table (SPLP SVOCs) PALs column has been revised to include the values listed in Table 2, corrected for a dilution factor of 2.1 as follows: naphthalene 2.9 µg/L, 2-methylnaphthalene 315 µg/L.

   b) **Due to the focused nature of this investigation, every effort should be made to ensure that the QLs achieve the project action levels. Therefore, SIM analysis is appropriate for this analysis (as is being done for soil samples) in order to ensure that the PAL for SPLP naphthalene is achieved. Please revise the worksheet accordingly.**

<u>Navy Response:</u>

Please see response regarding page 45, Worksheet 11, above.

4. **<u>Page 79, Worksheet #15-7: Reference Limits and Evaluation Table (SVOCs-Groundwater):</u>**
Due to the focused nature of this investigation, every effort should be made to ensure that the QLs achieve the project action levels. Therefore, SIM analysis is appropriate for this analysis (as is being done for soil samples) in order to ensure that the PALs for naphthalene and bis(2-ethylhexyl)phthalate are achieved. Please revise the worksheet accordingly.

<u>Navy Response:</u>

Please see response regarding page 45, Worksheet 11, above.

5. **<u>Page 93, Worksheet #19: Analytical SOP Requirements Table:</u>**
   a) **For SPLP SVOCs, the standard operating procedure (SOP) reference provided in Worksheet #19 indicates that SIM analysis will be performed. This is the preferred method that would allow the achievement of the naphthalene PAL. However, according to Worksheet #15-4, the full scan SVOC method is being utilized. Worksheet #15-4 should be updated to include the SVOC SIM QLs**

and subsequently, no modification would be needed for this worksheet. Ultimately, revisions must be made so both worksheets are consistent.

Navy Response:

Please see response regarding page 45, Worksheet 11, above. Full-scan SVOC analysis is being performed on the SPLP extract. The SOP reference on Worksheet #19 for SPLPS is a typo and has been corrected to 70.0011.

b) The sample volume for filtered metals and nitrate/sulfate analyses of groundwater needs to be changed from 50 mL to 250 mL.

Navy Response:

As detailed by footnote #2, the minimum sample volume is provided when it is different from (i.e., less than) the container volume. For filtered metals and nitrate/sulfate, the laboratory only requires 50 mL per test in order to perform the test without sacrificing data quality. This information is useful to the field team when available sample volume is limited. That being said, an attempt will be made to collect the samples in 250-mL bottles for these tests in case there is need for dilutions, reanalyses, and potential QA/QC issues.

c) The holding time for pH of soil samples must be changed from "not applicable" to "as soon as possible" as per the SW-846 method.

Navy Response:

Comment incorporated.

d) The holding time for sulfate/nitrate analyses of groundwater must be revised to clarify that the 28 day holding time is for sulfate.

Navy Response:

Worksheet #19 WCHEM row, "28 days (48 hours for nitrate)" has been changed to "28 days for sulfate, 48 hours for nitrate."

e) For SVOC analyses of soil samples, SPLP SVOC analyses of soil samples, SVOC analyses of groundwater samples, and filtered metals analyses of groundwater samples, please include the preparatory method SOP in column #3.

Navy Response:

SOPs and SOP references for these preparation methods have been included and also listed on Worksheet #23.

6. Page 95, Worksheet #20: Field Quality Control Sample Summary Table: The table is missing AOC E soil sampling in the smear zone (28-32 ft bgs), one sample from each location. Please update the worksheet accordingly.

Navy Response:

Worksheet #20, under AOC E Unsaturated Zone Soil Sampling (Month 26 or 29) cells in the No. of Sampling Locations column have been changed from 2 each to 4 each (2 locations, 2 sample depths per location). A footnote has been added with the notation that if a second treatment event is necessary, an additional 4 samples will be collected in a second sampling event.

7. Page 97, Worksheet #21: Project Sampling SOP References Table:

a) Please clarify if SOP A-6 (Soil Sampling for VOCs Using the EnCore Sampler) will be used. According to Worksheet #19, VOC soil samples will be collected directly into preserved vials in the field. Therefore, sampling with an EnCore sampler will not be required.

Navy Response:

An EnCore sampler is not required. Terra core samples will be collected instead. Encore sampler SOP has been removed from Worksheet #21 and replaced with a Terra core sampler SOP.

b) Please provide the SOP that will be used in the field for measuring persulfate in groundwater.

Navy Response:

The operational instructions for persulfate field test kit have been added to Worksheet #21 and included as Attachment F. See revised Worksheet #21 and Attachment F.

8. Page 99, Worksheet #22: Field Equipment Calibration, Maintenance, Testing and Inspection Table:

a) Please clarify how YSI multi-meter calibration procedures are different from the YSI pH probe and specific conductance probe calibration procedures.

Navy Response:

The YSI multi-meter probe calibration procedures are essentially the accumulation of calibration procedures for the YSI pH probe, YSI specific conductance probe, and YSI dissolved oxygen and temperature probe because the multi-meter measures pH, specific conductance, dissolved oxygen, and temperature. The multi-meter is included in the worksheet with the individual meters to account for potential meter availability.

b) Add the instrumentation that will be used to measure persulfate in the field and the corresponding maintenance and calibration procedures for this instrumentation.

Navy Response:

There is no instrument used to measure the persulfate concentration. The presence of persulfate will be assessed with a CHEMetrics/FMC test kit. It is a colorimetric test, no calibration is required.

9. Page 102, Worksheet #23: Analytical SOP References Table:

a) The analytical group associated with SOP 110.0032 needs to be changed from SPLPV and SPLPS to WCHEM, as shown in Worksheet #19.

Navy Response:

Comment incorporated. Also in the same row, column Modified for Project Work? (y/n) superscript has been removed from the N.

10. Page 109 Worksheet #25: Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table:

a) Please remove the rows for CVAA and the colorimeter as these instruments will not be used for this program.

Navy Response:

Comment incorporated.

b) Please revise the acceptance criteria for the pH meter to ±0.05 pH unit (not 0.1), as per Worksheet #24.

Navy Response:

Comment incorporated.

c) Please revise the acceptance criteria for the TOC analyzer to ±10% (not 15%), as per Worksheet #24.

Navy Response:

Fifteen percent is the limit as detailed by the method and the laboratory SOP. The ±10% limit cited in Worksheet #24 is incorrect and has been corrected to ±15%.

d) Please add SOP 70.0033 with the SOP references for GC/MS.

Navy Response:

Comment incorporated.

e) Please replace the pH SOPs with SOP 100.0112.

Navy Response:

Comment incorporated.

11. <u>Page 115, Worksheet # 28: Laboratory QC Samples Table</u>:

a) Worksheet #15 was referenced for the QC acceptance limits for LCS, LCSD, MS, and MSD recoveries and RPDs. The QC acceptance limits provided in Worksheets #15 for VOCs and SVOCs were the same for both soil and water matrices. Please check this with the laboratory as typically recovery limits vary between the soil and water matrices.

<u>Navy Response:</u>

Only the laboratory QA/QC limits for 2-methylnaphthalene are the same for both soil and water matrices. All QA/QC limits were re-verified.

b) Please revise the corrective action for the LCS for all VOC and SVOC analyses (Worksheets #28-1, 28-2, 28-3, 28-4, 28-6, and 28-7) to include the potential for recalibration if outside of the acceptance limits.

<u>Navy Response:</u>

To each of worksheets #28-1, 28-2, 28-3, 28-4, 28-6, and 28-7, the statement "LCS exceedances may indicate the need to recalibrate as described in Worksheet #24" has been inserted in the cell at the intersection of row Laboratory Control Sample (LCS) and column Corrective Action.

c) The QC acceptance limits provided for the LCS in Worksheet #28-2 reference Worksheet #15 which shows recovery criteria for full scan SVOC analyses. Since SIM analyses are being performed for the SVOC analyses of soil samples, the LCS criteria should be 45-135%, as per the laboratory's SOP. Please revise the worksheet accordingly.

<u>Navy Response:</u>

Comment incorporated.

d) The QC acceptance limits provided for surrogates in Worksheet #28-2 show recovery criteria for 3 surrogates from the laboratory's SOP for full scan SVOC analyses. However, as per the laboratory's SOP for SIM analysis (which is being performed), the required surrogate is benzo(e)pyrene-d12 and the recovery criteria are 45-135%. Please revise the worksheet accordingly.

<u>Navy Response:</u>

Comment incorporated.

e) The QC acceptance limits for surrogates for all VOC analyses (Worksheets #28-1, 28-3, and 28-6) show that it is acceptable for one surrogate to be outside of the acceptance limits. This is not acceptable and is not in accordance with the method or the laboratory's SOP; if one or more surrogates are outside of the acceptance criteria for VOC analyses,

reanalysis must be performed. It should be noted that validation guidelines also will qualify data if one or more surrogates are outside of the acceptance limits. Therefore, please revise the associated Worksheets accordingly.

Navy Response:

For the VOCs fraction, it is acceptable for one surrogate to be outside acceptance limits only if the exceedance is high and the sample is nondetect or if there is obvious chromatographic interference. This has been clarified on Worksheets #28-1, #28-3, and #28-6. Otherwise, the corrective action is to reanalyze.

f) The QC acceptance limits for surrogates for all SVOC analyses (Worksheets #28-2, 28-4. and 28-7) show that it is acceptable for one surrogate per fraction to be outside of the acceptance limits. This is acceptable but only if the recovery of that surrogate is greater than 10%. If one surrogate per fraction is outside of the acceptance limits and the recovery is less than 10%, corrective action must be performed. It should be noted that validation guidelines will reject data if one surrogate in a fraction exhibits less than 10% recovery. In addition, the laboratory's SOP also states the recovery must be greater than 10%. Therefore, please revise the associated Worksheets accordingly.

Navy Response:

Worksheets #28-2, #28-4, and #28-7, row "*Surrogate*" intersecting cells in columns "*Method/SOP QC Acceptance Limits*" and "Measurement Performance Criteria" the sentence "1 out allowed per fraction" has been changed to "1 out allowed per fraction if the surrogate outside the acceptance limits exhibits greater than 10 percent recovery."

g) Worksheet #28-7 shows that the laboratory is required to use the acid surrogates in all groundwater samples analyzed for SVOCs. Since the target compounds are all in the base-neutral fraction, the use of the acid surrogates will not be required. Please revise this worksheet accordingly.

Navy Response:

Worksheet #28-7, row Surrogates intersecting cell in column Measurement Performance Criteria, 2,4,6-Tribromophenol; 2-Fluorophenol; and Phenol-d5 have been removed from the surrogate list.

12. Page 133, Worksheet #30: Analytical Services Table:
Please update the number of Sample Locations to be consistent with Worksheet #20, which will be revised based on comment #8.

Navy Response:

It is assumed that this comment is referring to comment #6 and not comment #8. Worksheet #30 has been revised to reflect the correct number of soil samples stated in the response to comment #6.

13. Page 135, Worksheet #31: Planned Project Assessments Table:
Please have someone independent from the field team leader perform the field audits. PREQB suggests that the person who prepares the field audit report conduct the field audit.

Navy Response:

The fieldwork will be performed by a team of CH2M HILL personnel. The project manager and/or the field team leader will conduct the audit. The project manager and field team leader are both appropriate persons to perform the audit. Worksheet 9a has been revised to show Stephen Brand as primary project manager, with John Swenfurth as additional project manager. Worksheet 31 has been revised to show the field performance audit being conducted by "PM/FTL, CH2M HILL", and the safe work observations being conducted by a to be named later "FTL/SSC, CH2M HILL".

14. Page 143, Worksheet #33: OA Management Reports Table:
PREQB noticed that Brett Doerr, the Environmental Manager, is not listed as a recipient of the field audit report. Generally, the Environmental Manager receives this report. Please add his name to the recipient list, as appropriate.

Navy Response:

Brett Doerr does receive the field audit report, and has been added to the recipient list on Worksheet #33.

Page 6 - SAP Worksheet # 3 - Distribution List:
Change the name of PREQB president to Pedro J. Nieves, Esq. Also, please change his email to: pedronieves@jca.gobierno.pr

Navy Response:

Comment Incorporated.