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Final

Expanded Site Inspection Sampling and Analysis Plan UXO 15

Former Vieques Naval Training Range Vieques, Puerto Rico

Prepared for

Department of the Navy

NAVFAC ATLANTIC

Contract No.
N62470-08-D-1000
CTO-0037

May 2011

Prepared by

CH2MHILL

ES083110052506TPA

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Expanded Site Inspection Sampling and Analysis Plan
UXO 15

Former Vieques Naval Training Range
Vieques, Puerto Rico

Contract Task Order 0037

May 2011

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Atlantic Division

Under the

NAVFAC CLEAN 1000 Program
Contract N62470-08-D-1000

Prepared by

CH2MHILL

Virginia Beach, Virginia

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Acronyms and Abbreviations

AHA	activity hazard analysis
AMS	aerial magnetometer survey
ASTM	American Society for Testing and Materials
AVS/SEM	Acid volatile sulfide/simultaneously extracted metals
CA	corrective action
CCP	Comprehensive Conservation Plan
CCV	Continuing Calibration Verification
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
CLP	contract laboratory program
COC	chain of custody
CPC	Central Processing Center
CSM	Conceptual Site Model
CTO	Contract Task Order
DGM	digital geophysical mapping
DoD	U.S. Department of Defense
DOI	Department of the Interior
°C	degrees Celsius
DQE	data quality evaluation
DQI	data quality indicator
EADA	elevated anomaly density areas
EBS	Environmental Baseline Survey
ECA	Eastern Conservation Area
EIS	Environmental Information Specialist
EMA	Eastern Maneuver Area
EQB	Environmental Quality Board
ERA	Ecological Risk Assessment
ERA	Expanded Range Assessment
ERP	Environmental Restoration Program
ESSD	Explosive Safety Submission Determination
ft	feet/foot
FTL	Field Team Leader
FWS	Fish and Wildlife Service
GPS	Global Positioning System
GW	Groundwater
H&S	Health & Safety
HASP	Health and Safety Plan
HDPE	high-density polyethylene
HHRA	Human Health Risk Assessment

HQ	hazard quotient
ICAL	Initial Calibration
ICP	inductively coupled plasma
ICS	Interference Check Solutions
IDW	investigation-derived waste
IR	Navy Installation Restoration
IS	Internal Standards
LCS	laboratory control sample
LCL	lower control limit
LIA	Live Impact Area
LIMS	Laboratory Information Management Systems
LODs	limits of detection
LODV	Limit of Detection Verification
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCT	matrix conductivity threshold
MD	munitions debris
MDL	method detection limit
MEC	munitions and explosives of concern
mg/kg	milligrams per kilogram
mL	milliliter(s)
MPC	Measurement Performance Criteria
MPPEH	munitions potentially presenting an explosive hazard
MRAs	Munitions Response Areas
MSA	method of standard additions
MSOPPPs	Master Standard Operating Procedures, Protocols, and Plans
MS/MSD	matrix spike/matrix spike duplicate
N/A	not applicable
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
NIRIS	Navy Installation Restoration Information System
NOAA	National Oceanic and Atmospheric Administration
NOSSA	Naval Ordnance Safety and Security Activity
NPL	National Priorities List
OB/OD	open burn/open detonation
ORP	oxidation-reduction potential
OU	operable unit
PAL	project action limit
PDF	portable document format
PDS	post-digestion spike
PI	Photo Identified
PILs	project indicator limits
PM	Project Manager
POC	Point of Contact

PQO	Project Quality Objective
PREQB	Puerto Rico Environmental Quality Board
QA	quality assurance
QAMS	Quality Assurance Management Section
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	quality control
QL	quantitation limit
QSM	Quality Systems Manual
RAB	Restoration Advisory Board
RI	Remedial Investigation
RL	reporting limit
RPD	relative percent difference
RPM	Remedial Project Manager
RRT	relative retention times
RSL	Regional Screening Levels
RTK	Real Time Kinematic
SAP	Sampling and Analysis Plan
SI	Site Inspection
SIA	Surface Impact Area
SMP	Site Management Plan
SOP	standard operating procedure
SSC	Site Safety Coordinator
SSL	Soil Screening Level
SW	surface water
SWO	Safe Work Observation
TAT	turnaround time
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TOC	Total organic carbon
TRV	Toxicity Reference Value
U.S.	United States
UCL	upper confidence limit
UFP	Uniform Federal Policy
UFP -QAPP	Uniform Federal Policy-Quality Assurance Project Plans
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
UTLs	upper tolerance limits
UXO	Unexploded Ordnance
VNTR	Vieques Naval Training Range
VOA	volatile organic analytes
WCHEM	wet chemistry

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Executive Summary

This Sampling and Analysis Plan (SAP) is prepared to support the Expanded Site Inspection (ESI) field sampling activities at Photo Identified (PI) Sites PI 9 and PI 13, located within Unexploded Ordnance (UXO) Site 15, at the former Vieques Naval Training Range (VNTR) in the eastern portion of Vieques, Puerto Rico (**Figure 1**). This SAP includes 37 worksheets that detail various aspects of the environmental investigation process and serves as a guideline for the field activities and data assessment. This SAP was developed in general accordance with two guidance documents: 1) U.S. Environmental Protection Agency (USEPA), *EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5,* ***QAMS*** (USEPA, 2002), and 2) USEPA, *Uniform Federal Policy for Quality Assurance Project Plans* (UFP-QAPP) (Intergovernmental Data Quality Task Force, 2005).

This SAP was prepared under the United States Navy (Navy) Comprehensive Long-Term Environmental Action (CLEAN) Contract N62470-08-D-1000, Contract Task Order 0037, for submittal to the Naval Facilities Engineering Command (NAVFAC) Atlantic Division, USEPA Region 2, the Commonwealth of Puerto Rico Environmental Quality Board (EQB), and the United States Fish and Wildlife Service (USFWS). The Navy, USEPA, EQB, and USFWS work jointly as the Vieques Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Environmental Restoration Program (ERP) Technical Subcommittee.

UXO 15 is located within the Eastern Maneuver Area (EMA), one of four Munitions Response Areas (MRAs), and comprises PI 9 and PI 13 as areas warranting investigation (**Figure 1**). PI 9 was used for ammunition storage and PI 13 may have been the firing point from which rocket-related ordnance was launched to the Live Impact Area (LIA)/Surface Impact Area (SIA) (ERM, 2003). Interviews conducted during the Environmental Baseline Survey (EBS) (ERM, 2003) also suggests that PI 9 was used for ammunition disposal and small open burn/open detonation (OB/OD); however, the information on the OB/OD was likely interpreted incorrectly from Spanish translation; OB/OD operations did not likely take place at the site.

The Expanded Range Assessment/Site Inspection (ERA/SI) (CH2M HILL, 2010) identified isolated occurrences of munitions debris (MD) and munitions potentially presenting an explosive hazard (MPPEH) within the UXO 15 site (**Figure 2**). Additionally, two elevated anomaly density areas (EADAs) were identified (**Figure 3**). Small caliber casings and surface debris were located during the visual evaluation of the debris piles. The location and description of the items identified in the debris piles are shown in **Figure 4**. The ERA/SI recommended further investigation of the debris piles and near shore MD and evaluation of the potential ecological and human health risks.

The debris piles, MD, and MPPEH at UXO 15 have the potential to release chemical contaminants to the environmental media. As a result, an ESI is being conducted at UXO 15 to assess whether there have been releases of contamination and, if so, whether the contamination poses potentially unacceptable environmental and human health risks.

NOTE: THIS SUMMARY IS PRESENTED IN ENGLISH AND SPANISH FOR THE CONVENIENCE OF THE READER. EVERY EFFORT HAS BEEN MADE FOR THE TRANSLATIONS TO BE AS ACCURATE AS REASONABLY POSSIBLE. HOWEVER, READERS SHOULD BE AWARE THAT THE ENGLISH VERSION OF THE TEXT IS THE OFFICIAL VERSION.

NOTA: ESTE RESUMEN SE PRESENTA EN INGLÉS Y EN ESPAÑOL PARA LA CONVENIENCIA DEL LECTOR. SE HA HECHO TODO LO POSIBLE PARA QUE LA TRADUCCIÓN SEA PRECISA EN LO MÁS RAZONABLEMENTE POSIBLE. SIN EMBARGO, LOS LECTORES DEBEN ESTAR AL TANTO QUE EL TEXTO EN INGLÉS ES LA VERSIÓN OFICIAL.

The UXO 15 ESI will include the environmental characterization of surface soil and sediment. Surface soil will be collected as discrete surface soil samples in accordance with standard operating procedures (SOPs) A-2 and A-3 of the Master Standard Operating Procedures, Protocols, and Plans for the Environmental Restoration Program at Vieques (CH2M HILL, 2010a), denoted as the Master Plan in this SAP. Sediment will be collected in accordance with SOPs A-3 and G-2 of the Master Plan.

An estimated four surface soil samples and one sediment sample will be collected from beneath the debris piles (one sample beneath each pile) at UXO 15 and analyzed for constituents of interest (i.e., explosives, perchlorate, metals) and a supporting general chemistry parameter (pH). If other debris piles are found during the investigation, an additional soil sample will be collected beneath each. The debris piles will be removed from the site and properly disposed of prior to collection of the samples.

In addition to the above, digital geophysical mapping (DGM) will be accomplished at PI 9 and PI 13 and additionally at two magnetic anomaly areas outside of the two site boundaries. The DGM results will be conducted to determine if there are subsurface anomalies present at these sites. Any subsurface anomaly identified will be excavated; if the item removed is munitions and explosive of concern (MEC), then a subsurface soil sample will be collected below it and analyzed for explosives, perchlorate, and metals.

The data collected during the ESI will be used evaluated using the 7-step decision analysis process (**Figure 5**). Background data from Tl geologic unit will be used for metals comparisons. The 7-step decision analysis process will be used to determine whether additional investigation, remedial/removal action, or no further actions are warranted.

This SAP will help ensure that environmental data collected or compiled are scientifically sound, of known and documented quality, and suitable for the intended uses (i.e., environmental characterization, human health and ecological risk assessments, and path forward). The laboratory information cited in this SAP is for Katahdin Analytical Services, Inc. and Test America – West Sacramento, which will provide analytical services for this investigation.

Resumen Ejecutivo

Este Plan de Muestreo y Análisis (SAP, por sus siglas en inglés) ha sido preparado para apoyar las actividades de muestreo de campo de la Inspección Extendida del Sitio (ESI) en los Sitios Identificados con Fotografías Aéreas (PI) PI 9 y PI 13, ubicados dentro del Sitio de Municiones sin Detonar (UXO) Sitio 15, en el antiguo Campo de Adiestramiento Naval de Vieques (VNTR) en la porción este de Vieques, Puerto Rico (**Figura 1**). Este SAP, incluye 37 hojas de trabajo que detallan varios aspectos del proceso de investigación ambiental y sirven como guía para las actividades de campo y la evaluación de datos. Este SAP se desarrolló siguiendo las directrices de dos documentos guía: 1) *Guidance for Quality Assurance Project Plans, EPA QA/G-5,* ***QAMS*** (USEPA, 2002) de la Agencia de Protección Ambiental de los EEUU (USEPA), y 2) *Uniform Federal Policy for Quality Assurance Project Plans* (UFP-QAPP) (Intergovernmental Data Quality Task Force, 2005) de USEPA.

Este SAP se preparó bajo el Contrato Abarcador de Largo Plazo (CLEAN) de la Marina de los Estados Unidos (Marina) N62470-08-D-1000, Orden de Contrato 0037, para ser presentado al Comando de la División de Instalaciones de Ingeniería Naval Atlántico (NAVFAC), a la Región 2 de USEPA, la Junta de Calidad Ambiental de Puerto Rico (JCA), y el Servicio de Pesca y Vida Silvestre de EEUU (USFWS). La Marina, USEPA, JCA, y USFWS trabajan conjuntamente dentro del Subcomité Técnico del Programa de Restauración Ambiental de Vieques (ERP) bajo la ley de Respuesta, Compensación y Responsabilidad Ambiental (CERCLA).

UXO 15 está localizado dentro del Área de Maniobras del Este (EMA), una de cuatro Áreas de Respuesta a Municiones (MRAs), e incluye PI 9 y PI 13 que son sitios que ameritan ser investigados (**Figura 1**). PI 9 fue usado para almacenar municiones y PI 13 pudo haber sido el punto desde donde se disparaban municiones tipo cohete hacia el Área de Impacto con Bala Viva (LIA)/Área de Impacto de Superficie (SIA) (ERM, 2003). Las entrevistas que se llevaron a cabo en el Estudio Ambiental Base (EBS) (ERM, 2003), también sugieren que PI 9 fue utilizado como un sitio de disposición de municiones y un sitio de quema abierta/detonación abierta (OB/OD); sin embargo, la información sobre el sitio OB/OD fue posiblemente una mala interpretación en la traducción al español; se entiende que actividades OB/OD no ocurrieron en ese sitio.

Dentro del Sitio UXO 15, la Evaluación Expandida del Campo de Tiro /Inspección del Sitio (ERA/SI) (CH2M HILL, 2010) identificó la presencia aislada de escombros de municiones (MD) y municiones que potencialmente podrían presentar una amenaza de explosivos (MPPEH) (**Figura 2**). Además, se identificaron dos áreas con una densidad de anomalías elevadas (EADAs) (**Figura 3**). Durante la evaluación visual de las pilas de escombros, se observaron casquillos de balas de calibre pequeño y escombros sobre la superficie. La ubicación y descripción de los artículos que se identificaron en las pilas de escombros se muestran en la **Figura 4**. El ERA/SI recomendó que se lleven a cabo más investigaciones de las pilas de escombros y de los escombros de municiones (MD) que están cerca de la orilla, y se evalúen los riesgos potenciales tanto ecológicos como a la salud humana.

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Las pilas de escombros, MD, y MPPEH en UXO 15 tienen el potencial de dejar escapar contaminantes químicos al medio ambiente. Como resultado, se va a llevar a cabo un ESI en UXO 15, para evaluar si han habido escapes de contaminación, y de ser el caso, determinar si la contaminación presenta riesgos potenciales no aceptables, tanto ecológicos como para la salud humana

El ESI de UXO 15 incluirá la caracterización ambiental de suelo superficial y sedimento. Se recogerán muestras discretas de suelo superficial de acuerdo con los procedimientos de operación estándar (SOPs A-2 y A-3 de los Procedimientos de Operación Estándar, Protocolos, y Planes del Programa de Restauración Ambiental de Vieques (CH2M HILL, 2010a), los que en este SAP se denomina Plan Maestro. Se recogerán muestras de sedimentos de acuerdo con los SOPs A-3 y G-2 del Plan Maestro.

Se estima que en UXO 15 se recogerán cuatro muestras de suelo superficial y una muestra de sedimento debajo de las pilas de escombros (una muestra debajo de cada pila), que serán analizadas para los compuestos de interés (por ejemplo, explosivos, perclorato, metales) y un parámetro químico de apoyo general (pH). Si se encontraran otras pilas de escombros durante la investigación, se recogerá una muestra adicional de suelo debajo de cada pila. Las pilas de escombros serán removidas del sitio y serán dispuestas adecuadamente antes de que se recojan las muestras.

Además se llevará a cabo un estudio para generar mapas geofísicos digitales (DGM) en PI 9 y PI 13 y también en dos áreas con anomalías magnéticas fuera de los límites de los dos sitios. Los resultados DGM serán analizados para determinar si existen anomalías presentes en los subsuelos de estos sitios. Se excavará cualquier anomalía identificada en el subsuelo; y si los artículos encontrados son municiones y explosivos de preocupación (MEC por sus siglas en inglés), se recogerán muestras del suelo debajo de los artículos encontrados que serán analizadas para explosivos, perclorato, y metales.

Los datos recogidos durante el ESI serán utilizados y evaluados usando el proceso de análisis de decisión de 7 pasos (Figura 5). Para las comparaciones de metales se utilizarán datos de trasfondo de la unidad geológica T1. Se utilizará este proceso de 7 pasos para determinar si se necesita investigación adicional, acciones de remediación / remoción, o si es que no se necesitan nuevas medidas o acciones adicionales.

Este SAP ayudará a asegurar que los datos ambientales recogidos o compilados sean científicamente válidos, de calidad conocida y documentada y que sean adecuados para los usos previstos (es decir, para la caracterización ambiental, las evaluaciones de riesgo ecológico y para la salud humana, y para identificar los siguientes pasos a seguir). La información de laboratorio citada en este SAP, proviene de los laboratorios Katahdin Analytical Services, Inc. y Test América - West Sacramento, los cuales prestarán servicios de análisis para esta investigación.

SAP Worksheet #1 — Title and Approval Page

Final
Expanded Site Inspection Sampling and Analysis Plan
UXO 15
Former Vieques Naval Training Range
Vieques, Puerto Rico
May 2011

Prepared for:
Department of the Navy
Naval Facilities Engineering Command
Atlantic Division
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Contract N62470-08-D-1000
Contract Task Order – 0037

QA Review Signature:

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Brett Doerr
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Other Approval Signatures:

_____

Kevin Cloe
NAVFAC – Remedial Project Manager

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Daniel Rodriguez
USEPA Region 2 – Remedial Project Manager

_____

Wilmarie Rivera
PREQB – Remedial Project Manager

_____

Richard Henry
USFWS – Remedial Project Manager

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SAP Worksheet #2 — SAP Identifying Information

Site Name/Number: UXO 15 at the former Vieques Naval Training Range (VNTR), Vieques, Puerto Rico
Operable Unit (OU):
Contractor Name: CH2M HILL
Contract Number: N62470-08-D-1000
Contract Title: Navy Comprehensive Long-term Environmental Action—Navy (CLEAN) Program 1000
Work Assignment Number (optional): Contract Task Order (CTO) 0037 (Post-Munitions Investigation)

1. This SAP was prepared in general accordance with the requirements of the UFP-QAPP (Intergovernmental Data Quality Task Force, 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 Restoration Program/Munitions Response Program (ERP/MRP) Technical Subcommittee Meeting—New York, New York	July 14 and 15, 2010

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

Title	Date
Master Standard Operating Procedures, Protocols, and Plans, Environmental Restoration Program, Vieques, Puerto Rico, April 2010 (CH2M HILL)	April 2010

SAP Worksheet #2—SAP Identifying Information (continued)

6. Organizational partners (stakeholders) and connection with lead organization:
   - **USEPA Region 2 –** Federal regulatory stakeholder overseeing CERCLA Vieques ERP implemented by lead organization.
   - **Puerto Rico Environmental Quality Board (PREQB) –** Commonwealth regulatory stakeholder overseeing CERCLA Vieques ERP implemented by lead organization.
   - **United States Fish and Wildlife Service (USFWS) –** Land owner of land transferred from lead organization and on which UXO 15 ERP activities are conducted.
   - **National Oceanic and Atmospheric Administration (NOAA) –** Marine habitat stakeholder and technical advisor to USEPA.
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 (RPM)/Lead Agency Point of Contact (POC)	Navy	757-322-4736	kevin.cloe@navy.mil	A	CL	A
Dan Waddill	Vieques Program Coordinator/No project-specific role	Navy	757-322-4815	Dan.waddill@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	CL	A
John Noles	Biologist/Technical input	Navy	757-322-4891	john.noles@navy.mil	A		A
Jan Nielson	QA Officer	Navy	757-322-8339	Jan.nielsen@navy.mil	CD		
Aerial Iglesias	Branch Chief	USEPA	787-977-5890	iglesias.aerial@epa.gov	CL		CL
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
Sergio Lopez	Quality Control (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	EPA Region 2 ERRD/PSB/PST; Geology/Hydrogeology Lead	USEPA	212-637-4311	cutt.diana@epa.gov	A		A
Mindy Pensak	EPA Region 2 BTAG Coordinator/Ecological Risk Assessment (ERA) Lead	USEPA	732-321-6705	pensak.mindy@epa.gov	A		A
Mark Heaney	Technical Support Consultant for USEPA/USEPA contractor primary POC	TechLaw	516-508-1639	mheaney@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	Federal Facilities Coordinator/ Regulatory Agency POC	PREQB	787-767-8181 (x6129)	wilmarierivera@jca.gobierno.pr	A	CL	A
Scott Heim	Senior Ecologist	TRC	978-656-3583	sheim@trcsolutions.com	A		A
Katarina Rutkowski	Technical Support Consultant for EQB	TRC	860-298-6202	krutkowski@trcsolutions.com	CD		CD

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
Mike Barandiaran	Refuge Manager/No project-specific role	USFWS	787-741-2138	Mike_barandiaran@fws.gov			A
Susan Silander	Caribbean Islands Refuges Supervisor/No project-specific role	USFWS	787-851-7258 (x238)	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
Brett Doerr	Contractor Environmental Manager/ Navy contractor primary POC	CH2M HILL	757-671-6219	brett.doerr@ch2m.com	A	A	A
Bill Hannah	Technical Support	CH2M HILL	757-671-6277	bill.hannah@ch2m.com	A	A	A
John Swenfurth	Project Manager	CH2M HILL	813-874-0777	john.swenfurth@ch2m.com	A	A	A
Stephen Brand	Field Team Leader	CH2M HILL	757-671-6211	Stephen.brand@ch2m.com	A		A
Monica Marrow	Administrative Record Coordinator	CH2M HILL	757-671-6272	monica.marrow@ch2m.com			A
Bhavana Reddy	Data Manager	Critigen	703-462-3784	Forrest.cain@critigen.com			CD
Angela Barch	Environmental Information Specialist (EIS)	CH2M HILL	678-530-4073	Angela.barch@ch2m.com			CD
Barrie Selcoe	Human Health Risk Assessment Lead	CH2M HILL	281-721-8527	Barrie.selcoe@ch2m.com			CD
John Martin	Ecological Risk Assessment Lead	CH2M HILL	352-384-7122	John.martin@ch2m.com			CD
Mike Zamboni	Project Chemist	CH2M HILL	703-376-5301	mike.zamboni@ch2m.com			A
Anita Dodson	Navy Program Chemist	CH2M HILL	757-671-6218				CD
Mark Orman	Health & Safety Manager	CH2M HILL	414-847-0597	Mark.orman@ch2m.com	CD		
George DeMetropollis	UXO Safety Officer	CH2M HILL	619-687-0120	George.Demetropolis@ch2m.com	CD		
Paul Favara	Program QA Officer	CH2M HILL	352-335-5877	Paul.favara@ch2m.com			CD
Tamir Klaff	Geophysical Mapping	CH2M HILL	202-596-1199	Tamir.Klaff@ch2m.com			CD
to be determined (TBD)	UXO Avoidance for geophysics and soil sampling	CH2M HILL	N/A	N/A			CD
Kelly Perkins	Project Manager, POC at primary location	Katahdin Analytical Services, Inc.	207-874-2400 (x17)	kperkins@katahdinlab.com			CD

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
Nilo Ligi	Project Manager, POC	Test America – West Sacramento	916-374-4427	Nilo.Ligi@testamericainc.com			CD
Laura Maschoff	Project Manager	DataQual Environmental Services, LLC	314-330-1327	dataqual@charter.net			CD
Jim Keesee	Project UXO Site Manager for vegetation clearance, debris removal and anomaly excavation	USA Environmental, Inc.	813-391-9731	jkeesee@usatampa.com			CD
Michael P. Connelly Pagán	N/A	Restoration Advisory Board (RAB)	787-741-4442	mpcbieke@yahoo.com		CD	
Michael Diaz	N/A	RAB	787-667-2804	diazmmdo@aol.com		CD	
Wanda Bermudez	N/A	RAB	787-435-2841	wbromero@yahoo.com		CD	
Adalina Cruz Colon	N/A	RAB	N/A	N/A		CD	
Christina Corrada Emmanuel	N/A	RAB	939-243-3388	N/A		A	
Colleen McNamara	N/A	RAB	787-380-2545	lacolina@hughes.com		CD	
Stacie D. Notine	N/A	RAB	N/A	N/A		HC	
Jorge Fernandez -Porto	N/A	RAB	787-726-2839	jfporto@onelinkpr.net		CD	
Hector Julian Camacho	N/A	RAB	787-741-8261	vieques357@yahoo.com		CD	
Luis Lionel Sanchez Carambot	N/A	RAB	787-241-0063	sanchezcarambot@yahoo.com		CD	
Lirio Marquez-D'Acunti	N/A	RAB	787-726-2839	liriomarquez@gmail.com		CD	

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
Anita Dodson	CH2M HILL/Navy Program Chemist/ SAP review	757-671-6218			
John Swenfurth	CH2M HILL/Contractor Project Manager (PM)/Logistics and administration	813-874-0777			
Mark Orman	CH2M HILL/Contractor Health and Safety Lead/Health and Safety officer	414-847-0597 414-712-4138 (cell)			
Angela Barch	CH2M HILL/Environmental Information Specialist (EIS)/Data tracking and management	678-530-4073 404-353-7737 (cell)			
Barrie Selcoe	CH2M HILL/Human Health Risk Assessment Lead	281-721-8527 713-392-8707 (cell)			
Paul Favara	CH2M HILL/ Program QA Officer	352-335-5877			
Stephen Brand	CH2M HILL/ Field Team Leader (FTL)/ Site Safety Coordinator (SSC)	757-671-6211 757-285-7685 (cell)			
Mike Zamboni	CH2M HILL/Project Chemist	703-376-5301			
Kelly Perkins	Katahdin Analytical Services, Inc./Project Manager	207-874-2400 (x17)			
Nilo Ligi	Test America – West Sacramento/Project Manager	916-374-4427			
Laura Maschoff	DataQual Environmental Services, LLC/Data Validator/Project Manager	314-330-1327			
Jim Keesee	USA Environmental, Inc./Site Manager/UXO subcontractor for vegetation removal, debris removal, and anomaly excavation	813-391-9731			
Tamir Klaff	CH2M HILL/DGM Lead/Geophysical Mapping	202-596-1199			
Bhavana Reddy	Critigen Project/Data Manager	703-462-3784			

Signed versions of Worksheet #4 will be kept on file at CH2M HILL along with other project documents.

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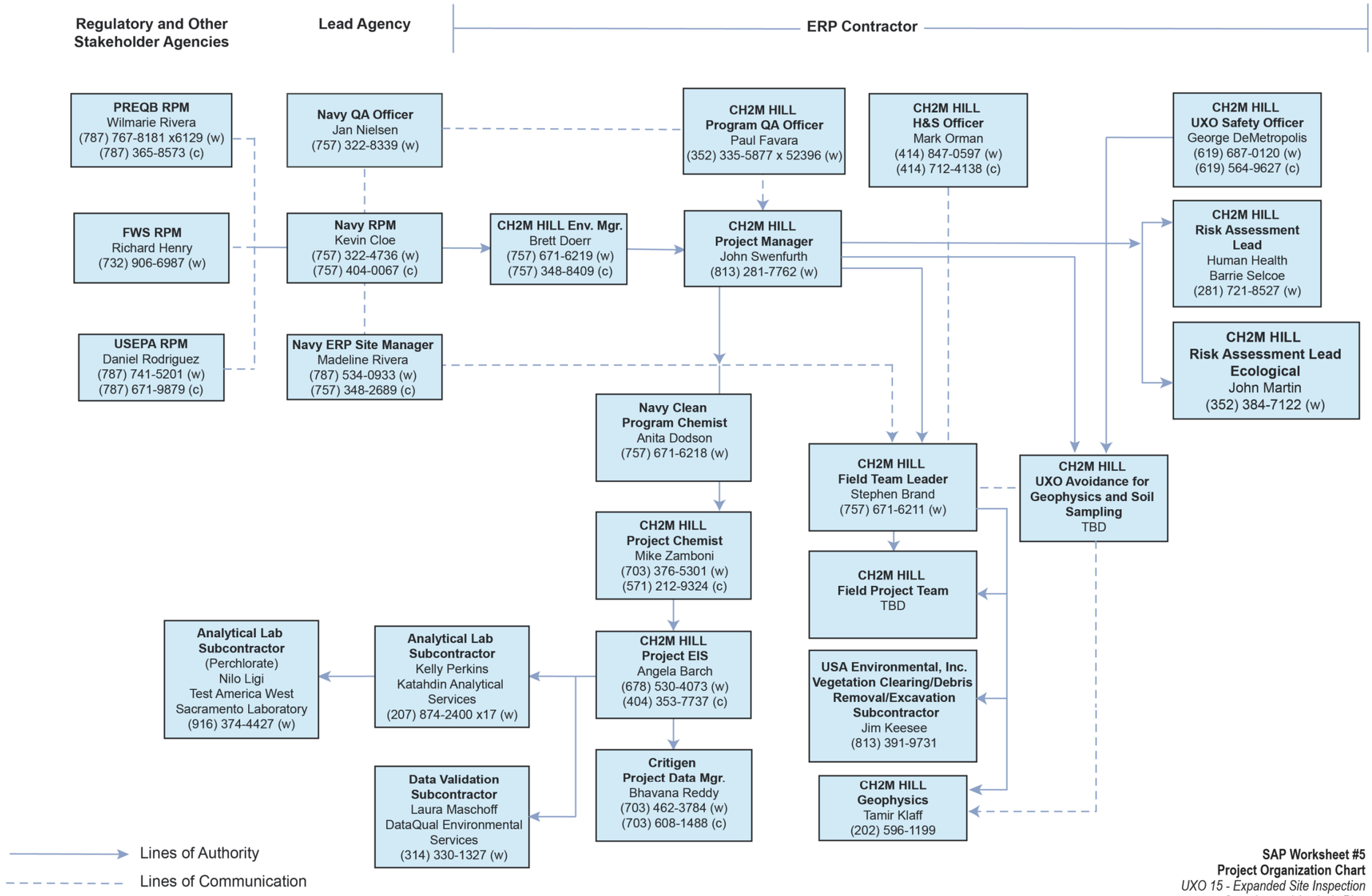
SAP Worksheet #5—Project Organizational Chart



SAP Worksheet #5
Project Organization Chart
UXO 15 - Expanded Site Inspection
Samping and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

ES083110052506TPA UXO 15 - Expanded SI - Worksheet 5-rev4.ai

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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.
Significant Analytical Laboratory QA/QC Issues	Navy RPM	Kevin Cloe	757-322-4736	If significant laboratory QA/QC issues are identified that impact the usability of the data, then, the Navy RPM shall notify the Navy Chemist. The Navy chemist may then determine what corrective actions should be taken with respect to the laboratory accreditation process.
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 (x6129)	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.
Communication to/from USFWS (e.g., receipt of SAP for review; submission of USFWS comments)	USFWS RPM	Richard Henry	732-906-6987	Primary POC for USFWS (via e-mail, telephone, hardcopy, or in-person, as warranted); can delegate communication to other internal or external points of contact.
Navy QA/ QC input	Navy Quality Assurance Officer (QAO)	Janice Nielsen	757-322-8339	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	813-874-0777	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 sampling activities; SAP changes in the field	CH2M HILL FTL	Stephen Brand	757-671-6211	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.
Field corrective actions	CH2M HILL FTL	Stephen Brand	757-671-6211	See Worksheet 32 Assessment Findings and Corrective Action (CA) Responses and Worksheet 32-1 CA Form.

SAP Worksheet #6 — Communication Pathways (continued)

Communication Drivers	Responsible Affiliation	Name	Phone Number	Procedure
Daily Field Progress Reports	CH2M HILL FTL	Stephen Brand	757-671-6211	FTL will call to contractor PMs daily
Ensure staff health and safety in the field	CH2M HILL SSC	Stephen Brand	757-671-6211	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	Angela Barch	678-530-4073 404-353-7737 (cell)	EIS will track data from sample collection through upload to database, ensuring Quality Assurance Project Plan (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 (Katahdin Analytical Services, Inc.)	Kelly Perkins	207-874-2400 x17	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.
Reporting Lab Data Quality Issues	Laboratory PM (Test America – West Sacramento)	Lilo Nigi	916-374-4427	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, release of analytical data for upload to database	CH2M HILL Project Chemist	Michael Zamboni	703-376-5301	See Worksheets 24, 25, and 28 for analytical CAs; 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).
Significant Analytical Laboratory QA/QC Issues	CH2M HILL Project Chemist	Michael Zamboni	703-376-5301	If significant laboratory QA/QC issues are identified that impact the usability of the data, then the project chemist will inform the navy project manager as soon as possible, within 2 business days.
Technical Support and Reporting	CH2M HILL Senior Technologist	John Martin and Barrie Selcoe	352-384-7122 281-721-8527	Risk assessment leads, data evaluation, analysis, and reporting
Validated data	Data Validator PM (DataQual Environmental Services, LLC)	Laura Maschoff	314-330-1327	Data validator provides data validation reports (electronic and hardcopy) that provide the data qualifiers and associated explanations.
Geophysical Mapping	CH2M HILL Geophysical Mapping	Tamir Klaff	202-596-1199	Will gather geophysical data and communicate to the Project Manager the results.
Vegetation Clearing, debris removal, and subsurface anomaly excavation	USA Environmental, Inc.	Jim Keesee	813-391-9731	Field avoidance of UXO, UXO safety while conducting field activities which include vegetation clearance, debris removal, and anomaly excavation.
UXO avoidance during soil sampling and geophysical surveying	CH2M HILL	TBD	N/A	UXO avoidance specialist will report to the Project Manager on status of work.

SAP Worksheet #7 — Personnel Responsibilities Table

Name	Title	Organizational Affiliation	Responsibilities
Kevin Cloe	Vieques RPM	Navy	ERP activities implemented under this SAP
Jan Nielson	QAO	Navy	Navy review of SAP and QA input
Madeline Rivera	Vieques ERP Site Manager	Navy	On-island Navy liaison; provides logistical support for implementation of environmental restoration program activities under this SAP
Brett Doerr	Environmental Manager	CH2M HILL	Responsible for ERP at Vieques; primary Navy contractor POC; assists in data evaluation and interpretation; reviews report
John Swenfurth	PM	CH2M HILL	Project administration; coordinates staffing; monitors project performance; directs and oversees project staff
Barrie Selcoe	Senior Technologist	CH2M HILL	As the technical lead, support human health risk screening.
John Martin	Senior Ecologist	CH2M HILL	As the technical lead, support ecological risk screening.
Anita Dodson	Program Chemist	CH2M HILL	Provides program level review and support of the UFP-SAP.
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
Stephen Brand	FTL/SSC/Project Scientist	CH2M HILL	Supervises sampling and coordinates field activities; ensures onsite compliance with work plan; oversees and ensures safety of onsite personnel; responsible for use and completion of all field work related Health & Safety (H&S) paperwork; support ecological risk assessments
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
Angela Barch	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
Bhavana Reddy	Database Manager	CH2M HILL	Uploads validated data to environmental database
Tamir Klaff	Geophysics Lead	CH2M HILL	Coordinate all geophysics activities on site
TBD	UXO Avoidance	CH2M HILL	UXO avoidance during geophysics and soil sampling.
Leslie Dimond	Quality Assurance Manager	Katahdin Analytical Services, Inc.	Responsible for laboratory QA program and review of QC data
Dr. Doug Weir	Quality Assurance Manager, Project Manager	Test America _ West Sacramento	Responsible for laboratory QA program and review of QC data. Overall manager for analytical work at Test America West Sacramento.

SAP Worksheet #7 — Personnel Responsibilities Table (continued)

Name	Title	Organizational Affiliation	Responsibilities
Kelly Perkins	Project Manager, primary Point of Contact	Katahdin Analytical Services, Inc.	Laboratory POC and overall manager for analytical work
Laura Maschoff	Project Manager and Data Validator	DataQual Environmental Services, LLC.	Responsible for validating analytical data in accordance with project-specific UFP-SAP
Jim Keesee	UXO Site Manager	USA Environmental, Inc	Responsible for all vegetation clearance, debris removal, and excavation of anomalies.
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.

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	UXO Tech II or better training	U.S. Department of Defense	Training will be verified as current prior to starting field activities by SSC.	Subcontracted UXO Tech II or better	Subcontracted UXO Tech TBD	Subcontractors records and CH2M HILL field safety files

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SAP Worksheet #9 — Project Scoping Session Participants Sheet

Project Name: Expanded Site Investigation (ESI) Sampling, UXO 15, Former VNTR	
Projected Date(s) of Sampling: January 2011	**Site Name:** UXO 15
PM: John Swenfurth	**Site Location:** Vieques, Puerto Rico
Dates of Session: July 14 and 15, 2010 **Scoping Session Purpose:** Discuss Conceptual Site Model (CSM) and concur upon the ESI objectives, technical approach, and decision structure.	

Name	Title	Affiliation	Phone #	E-mail Address	Project Role
Kevin Cloe	Vieques RPM	Navy	757-322-4736	kevin.cloe@navy.mil	Primary Navy POC
Daniel Hood	Vieques RPM	Navy	757-322-4630	daniel.r.hood@navy.mil	Navy POC for munitions related items
Stacin Martin	Senior Technical Advisor	Navy	787-322-4780	Stacin.martin@navy.mil	Navy additional POC for munitions related items
Daniel Rodriguez	Vieques RPM	USEPA	787-741-5201 787-671-9879 (cell)	Rodriguez.daniel@epamail.gov	Primary USEPA 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
Sergio Lopez	Quality Assurance	USEPA	732-321-6778	lopez.sergio@epa.gov	QC Specialist/Technical input and draft document review
Mindy Pensak	Ecological Risk Assessment Lead	USEPA	732-321-6705	Pensak.mindy@epa.gov	Technical input and draft document review
Tom Hall	MEC Support Contractor to EPA	TECHLAW	501-753-7987	THall@TechLawInc.com	Technical input and review of munitions related items on behalf of EPA
Wilmarie Rivera	Vieques RPM	PREQB	787-767-8181 x 6141	wilmarierivera@jca.gobierno.pr	Primary PREQB POC.
Jim Pastorik	Technical Support Contractor to PREQB	UXO PRO MEC	703-548-5300	jim@uxopro.com	Technical input and review of munitions related items on behalf of EQB
Katarina Rutkowski	Technical Support Contractor to PREQB, 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

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

Project Name: Expanded Site Investigation (ESI) Sampling, UXO 15, Former VNTR	
Projected Date(s) of Sampling: January 2011	**Site Name:** UXO 15
PM: John Swenfurth	**Site Location:** Vieques, Puerto Rico
Dates of Session: July 14 and 15, 2010 **Scoping Session Purpose:** Discuss CSM and concur upon the ESI objectives, technical approach, and decision structure.	

Name	Title	Affiliation	Phone #	E-mail Address	Project Role
Diane Wehner	Ecological Risk Assessor	NOAA	732-872-3030	Diane.wehner@noaa.gov	Technical input and draft document review/No project-specific role.
Richard Henry	Vieques RPM	USFWS	732-906-6987	Richard_henry@fws.gov	Primary USFWS POC/No project-specific role
John Tomik	Activity Manager	CH2M HILL	757-671-6259	john.tomik@ch2m.com	Vieques Activity Manager
Brett Doerr	Environmental Manager	CH2M HILL	757-671-6219	brett.doerr@ch2m.com	Navy contractor primary POC
John Martin	Ecological Risk Assessor	CH2M HILL	352-384-7122	john.martin@ch2m.com	Navy contractor lead ecological risk assessor
Barrie Selcoe	Human Health Risk Assessor	CH2M HILL	281-721-8527	barrie.selcoe@ch2m.com	Navy contractor lead human health risk assessor
Tamir Klaff	Geophysicist	CH2M HILL	703- 669-9611	tamir.klaff@ch2m.com	Navy contractor lead geophysicist

Comments/Decisions: See meeting minutes from July 14 and 15, 2010 ERP/MRP Subcommittee Meeting below.

Action Items: See below

Consensus Decisions: See below

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

The following is a summary of the main points from the July 14 and 15, 2010 Environmental Restoration Program/ Munitions Response Program Technical Subcommittee Meeting Minutes (Final). Figure numbers have been edited to match the current figures identified in this SAP.

UXO 15 ESI Scoping Session

The Navy and CH2M HILL completed an internal scoping session and reviewed applicable guidance (with internal experts) to pull together a "seed file" that will be useful in starting the team conversations for the UXO 15 ESI. The "seed file" contains the elements of the CSM (i.e., site descriptions and physical characteristics, potential sources, potential contaminants, release mechanisms), as well as the proposed approach for the ESI.

Characterization Approach

Surficial Debris/Munitions Items

The only debris in the shallow marine environment that will be removed is that which is above water and/or will not damage coral formations or other ecological habitat by being removed. Since the debris is just metals casings, and may be providing habitat for marine species, including coral, its removal is only being done for aesthetic purposes.

TechLaw states that the items in the shallow marine environment need to be further investigated before it is stated that they are likely inert items.

Consensus Decisions

The Navy, EPA, EQB, and Fish and Wildlife Service (FWS) concurred upon the CSM elements and proposed approach, with the following modifications:

- Although any given scrap metal may not be a hazardous substance under CERCLA, it may deteriorate and release hazardous substances to the environment which could be subject to regulation under CERCLA.
- While isolated or small piles of metallic debris may not warrant sampling as potential source areas, potential releases from larger piles should be characterized. Therefore, in addition to the characterization approach described in the meeting minutes, soil samples will be collected under the five large piles observed (A through E identified in the meeting materials and shown in **Figure 4** for location and **Figures 6 thru 12** for photographs of the debris piles) following their removal.
- One soil sample will be collected beneath each large debris pile, at a minimum from beneath the five aforementioned piles. If other piles of comparable size are found during the investigation, an additional soil sample will be collected beneath each. With respect to the interval from which the soil samples will be collected, if the debris or item at a particular location is solely MEC, the soil sample will be collected from the 2-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris or item at a particular location is not or does not contain MEC, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris

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

- at a particular location is a mixture of MEC and non-MEC items, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal.

Action Items

Navy – Prepare a draft SAP in accordance with UFP-QAPP guidance for regulatory review.

SAP Worksheet #10 — 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 ESI sampling activities.

Site Background

The former VNTR (**Figure 1**) consists of approximately 14,600 acres and is divided operationally into four MRAs that from west to east comprise: the 11,000-acre EMA; the 2,500-acre SIA; the 900-acre LIA; and the 133-acre Eastern Conservation Area (ECA) (**Figure 1**). The former VNTR was transferred from the Navy to the Department of Interior (DOI) in 2003 to be managed by USFWS as part of the National Wildlife Refuge System. While all military activities have ceased at the former VNTR, the Navy retains responsibility for any MEC and/or environmental contaminant concerns attributable to past Navy activities that may exist.

UXO 15 is located within the EMA and comprises PI 9 and PI 13 as areas warranting investigation (**Figure 1**). Interviews conducted during the EBS (ERM, 2003) suggest PI 9 was used for munitions storage and disposal and small open burn/open detonation (OB/OD). However, the OB/OD information was likely interpreted incorrectly from Spanish translation; OB/OD operations did not likely take place. It was documented in the EBS that PI 13 may have been the firing point from which rocket-related ordnance was launched to the LIA/SIA (ERM, 2003). However, no evidence of this use has been observed at the site during the site visits.

Investigation History

In 2005, the VNTR was placed on the National Priorities List (NPL) and response activities are conducted under the CERCLA. The NPL requires environmental restoration activities for Navy Installation Restoration (IR) sites on Vieques to be conducted under CERCLA unless and until removed from CERCLA authority.

A Preliminary Range Assessment (CH2M HILL, 2003) identified PI 9 as a potential munitions response site based on aerial photograph analysis (ERI, 2000). The Phase I RCRA Facility Investigation (RFI) Report recommended PI 9 for further evaluation for munitions and munitions constituents under the Munitions Response Program (MRP) and an inspection of potential MEC at PI 13 (CH2M HILL, 2004).

The Expanded Range Assessment/Site Inspection (ERA/SI) Report (CH2M HILL, 2010) identified MD and MPPEH items and five debris piles at UXO 15 based on transect and aerial survey results (**Figure 2**). Small caliber casings and surface debris were located during visual evaluation of the debris piles. The location and description of the items identified in the debris piles are shown in **Figure 4**. Visual transects across UXO 15 identified 32 MD items on the surface. In addition, MD items were also identified offshore in the eastern portion of PI 9. The munitions items cannot be positively identified offshore due to their deteriorated state, but are

empty munitions casings that have been incorporated into the reef material (**Figures 13 and 14)**. During an aerial magnetometer survey (AMS), two EADAs were identified (**Figure 3**).

The ERA/SI recommended further investigation of the debris piles and near shore MD and evaluation of the potential ecological and human health risks. Offshore and underwater munitions items are associated with UXO 16 and generally will be addressed under UXO 16; however, munitions items identified above the low tide water level just offshore of PI 9 will be removed as part of UXO 15 and this SAP for aesthetic purposes.

Conceptual Site Model

Figure 15 presents the generalized conceptual site model of UXO 15, the key elements of which are described below. The purpose of this ESI is to evaluate whether there have been contaminant releases at UXO 15 warranting further investigation or action. The elements of the CSM presented below are pertinent to developing the ESI approach and therefore includes the physical characteristics, potential release mechanisms, potential constituents released, future land use, and potential receptors.

Physical Characteristics

Most of UXO 15 is characterized as rocky land where rock outcrops exist on 50 to 70 percent of the surface. Loose stones with very shallow soil material are found between the outcrops. PI 9 additionally contains tidal flats and a tidal swamp. The tidal flats are slightly above sea level, affected by sea water at high tide, and have a high salt concentration. The tidal swamp is covered with thick mangroves and immersed in salt water the majority of the year.

UXO 15 is characterized by the TI geological zone of marine sedimentary rocks. In topographically elevated areas, such as in the central area of the peninsula (**Figure 16),** limestone and dolomite are exposed at the ground surface.

Surface water bodies bound three sides of UXO 15. Puerto Mosquito is located to the west and Puerto Ferro to the east. The ocean is to the south. There is also a small lagoon between the two PI 9 areas, a small lagoon in the southwest portion of UXO 15, and a small lagoon adjacent to debris piles A and E (**Figure 4**). Debris pile E is located on sediment within the intertidal zone of the lagoon.

The soil overburden is believed to be thin in most places, and groundwater (GW) likely exists primarily in bedrock. Groundwater may exist in overburden closer to the surface water bodies. Groundwater likely discharges to the lagoons to the east and west, and to the ocean to the south. Discharge is likely to be tidally influenced. Based on condition encountered at similar sites around Vieques, the general groundwater geochemistry is believed to be brackish to saline and hard.

SAP Worksheet #10 — Problem Definition (continued)

Future Land Use

The former VNTR was transferred to the DOI in 2003 to be managed by USFWS as part of the National Wildlife Refuge System, pursuant to Section 1049 of the National Defense Authorization Act for Fiscal Year 2002 (Public Law 107-107).

A Comprehensive Conservation Plan (CCP) for the Vieques National Wildlife Refuge was completed by USFWS, which outlines the land use plan for managing the former VNTR as a wildlife refuge (DOI, 2007). Hiking and biking trails have been proposed for the area encompassed by UXO 15.

Potential Source of a CERCLA Releases and Release Mechanisms

The potential sources of release at UXO 15 are:

- Munitions-related items, empty Marine artillery casings within UXO 15 (**Figure 2**); however, it is important to note that UXO was not identified at each site
- Five debris piles identified at various locations along the road within UXO 15, just north of UXO 15, and in the shallow marine area at PI 9 (**Figure 4**)
- Potential subsurface items related to historical activities associated with PI 9 and PI 13

Based on the type of material present at the site and the historical information on potential munitions items the release mechanism is listed below:

- Deterioration of material (debris or munitions) and its potential release by leaching to underlying soil.

The UXO 15 ESI will include the environmental characterization of soil and sediment beneath debris piles and any subsurface MEC identified. Groundwater will not be characterized (at least initially) as part of this investigation, since: 1) the primary groundwater discharge points are the ocean and large lagoons; 2) groundwater will not flow to other areas of Vieques where it could impact existing or future groundwater users; 3) groundwater use cannot occur at UXO 15 due to development restriction at the site by a Congressional Order; and 4) the general groundwater geochemistry would be hard (due to the limestone bedrock) and brackish to saline as it is likely tidally influenced and subject to saltwater mixing. However, the final determination of whether groundwater evaluation is warranted will be deferred until after the other media have been sampled and their data evaluated. Evaluation of the data to help make this determination will include reviewing soil and sediment data to determine the potential for contaminants to leach to groundwater (i.e., fate and transport mechanisms).

Potential contaminants of interest from the munitions and debris items identified comprise explosives, perchlorate, and inorganic constituents (i.e., metals).

Receptors

Data collected as part of this ESI will be compared to conservative ecological and human health screening values. If exceedances are identified, more realistic qualitative evaluations are conducted (if possible), which may include consideration of actual or likely receptors. Quantitative risk evaluations will not be conducted as part of the ESI.

SAP Worksheet #10 — Problem Definition (continued)

Potential receptors at the site include both human and ecological, as discussed below.

Human Health

Recreational users may access UXO 15 by sea in some areas where steep cliffs are not present; recreational users may also access UXO 15 by land. In addition, USFWS workers may be present at the site to conduct law enforcement activities and maintenance activities of proposed roads and trails.

Ecological

Potentially complete exposure pathways exist for terrestrial receptors exposed to surface soil, and aquatic receptors exposed to surface sediment. The receptors include:

- Terrestrial – plants, soil invertebrates, birds, mammals, and reptiles exposed to surface soil
- Aquatic – benthic invertebrates, aquatic plants (e.g., mangroves), birds, and mammals exposed to surface sediment in mangrove wetland habitat

Problem Statement

The ERP/MRP Technical Subcommittee met July 14 and 15, 2010 to scope and agree upon the rationale, sampling approach, and analysis for the UXO 15 ESI. Because the debris and munitions-related items have been identified within UXO 15, but is unknown whether there have been releases of contaminants from this material, an ESI is warranted to determine if there has been a release(s) of hazardous constituents from the debris piles or potential munitions items to environmental media and, if so, whether further investigation or action is warranted.

Based on the CSM and secondary data evaluation, it is possible that explosives and inorganics have been released as a result of the historical operations.

Environmental Questions to be Answered by the ESI Sampling:

To address the Problem Statement defined above, the following environmental questions will be answered via implementation of this SAP:

1. Have there been releases of hazardous constituents to the surrounding soil/sediment from the debris piles?

   The debris piles (and any obviously contaminated soil) will be removed and one discrete soil/sediment sample will be collected beneath each of the five large debris piles identified (the samples beneath debris piles A through D are assumed to be soil and the sample beneath debris pile E is assumed to be sediment). Following vegetation clearance, a visual survey across PI 9 and PI 13 will be conducted for any debris on the surface to facilitate the DGM survey. If other debris piles of comparable size are found during the investigation, they will be removed and an additional discrete soil/sediment

SAP Worksheet #10 — Problem Definition (continued)

sample will be collected beneath each. One sample per debris pile was determined to be sufficient based on the relatively small size of the piles (i.e., less than approximately 10ft x 10ft).

2. Are there subsurface items present within PI 9 and PI 13 and the EADAs?

   DGM of these areas will determine if subsurface items are present. Excavation, identification, and removal of anomalies (if non native) will help ensure subsurface items are addressed. If the items are MEC, subsurface soil samples will be collected directly below them in a manner consistent with the aforementioned surface soil samples to determine if there have been releases to the underlying soil.

   If releases to soil and/or sediment are identified, what are the appropriate next steps?

   This determination will be made based on screening the data using the 7-step decision tree (**Figure 5**).

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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?

The Navy, USEPA, EQB, and USFWS will use the data collected during the ESI Sampling (as well as relevant historical data) at UXO 15 to make determinations of whether CERCLA-related releases took place and, if so, whether further investigation or action is warranted. Therefore, the site-specific data uses are defined in Item 5 of this worksheet.

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

The PALs are defined in the Master Standard Operating Procedures, Protocols, and Plans (CH2M HILL, 2010a) and are listed, by constituent group and medium, in Worksheet #15. In general, the PALs are:

- Vieques human health screening values for soil are the current (as of the time the ESI is being conducted) Regional Screening Levels (RSLs) (adjusted for a hazard quotient [HQ] of 0.1 for non-carcinogens) provided by USEPA.
- Vieques ecological screening values for soil, which are listed in the Vieques Master Ecological Risk Assessment Protocol (CH2M HILL, 2010a) and associated Master ERA Protocol Update 1 (CH2M HILL, 2010c).
- Vieques soil-to-groundwater leaching screening values provided by USEPA.
- Vieques discrete surface soil inorganics screening values are the East Vieques background soil inorganics upper tolerance limits (UTLs) (CH2M HILL, 2007).
- Where a specific project action limit (PAL) deviates from the above, it is footnoted in the applicable Worksheet #15 table.
- Results for screening data (i.e., general chemistry parameter pH) collected to support the interpretation of ecological risk results will not be compared to strictly-defined PALs, but will be evaluated qualitatively. This parameter is identified in Worksheet #15. There are no project indicator limits (PILs); pH results will be the only screening data generated.
- In addition to listing the particular analytes, project action limits (PALs), and limits of quantitation (LOQs), Worksheet #15 identifies where limits of detection (LODs) are greater than PALs. Even though LODs may be greater than certain PALs, detection limits (DLs) may be closer to or less than PALs. When this occurs, and if a constituent is detected in a sample at or at greater than the PAL, then it is reported, qualified as applicable. The majority of the constituents have LODs less than PALs. For constituents with LODs greater than PALs, the majority have DLs less than PALs. For the following constituents, the DL is still greater than the PAL: hexavalent chromium (SSL), 1,3-dinitrobenzene (SSL), nitrobenzene (SSL and marine sediment Toxicity Reference Value (TRV)), 2,4-dinitrotoluene (SSL), 2-nitrotoluene (SSL), 3-nitrotoluene (SSL), and 4-nitrotoluene (SSL).

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

The Vieques screening values on which the PALs are based are not of equal importance. Therefore, decisions with respect to a particular constituent can still be made when the DL is greater than the PAL. The SSLs are more qualitative than human health and ecological screening values. Past experience at Vieques has demonstrated that SSLs are not reliable predictors of leaching to groundwater; they are overly conservative (see multiple site-specific SSL discussions contained in the Site Inspection/Expanded Site Inspection Report [CH2M HILL, 2010d).

3. **What types of data are needed (matrix, target analytes, analytical groups, field screening, on-site analytical or off-site laboratory techniques, sampling techniques)?**
   - Soil and sediment samples will be submitted to an offsite laboratory for analysis (Katahdin Analytical Services, Inc. of Scarborough, Maine and for perchlorate Test America West Sacramento
   - Chemicals of interest consist of explosives constituents and metals, as shown in Worksheet #15
   - Worksheets #15, and #18 define the matrices, analytical groups, and, where applicable, specific target analytes for UXO 15
4. **How "good" do the data need to be in order to support the environmental decision?**
   - The data will be of the quantity and quality necessary to provide technically sound and defensible assessments of the site conditions and potential risks at UXO 15. Laboratory methods will meet CERCLA, USEPA Region 2, and Navy guidance and the data will be validated by a third-party validator using national functional guidance, methodology, and laboratory Standard Operating Procedures (SOPs) as described in Worksheet #36
   - The laboratory will follow the Measurement Performance Criteria (MPC) in Worksheet #12 for field QC samples and Worksheet #28 for laboratory QC samples. These MPC are consistent with the U.S. Department of Defense (DoD) Quality Systems Manual (QSM) as applicable and laboratory in-house limits where the QSM does not apply.
5. **How much data should be collected (number of samples for each analytical group, matrix, and concentration)?**
   - Worksheet #18 contains the number of samples per matrix per analytical group for UXO 15. Worksheets #15 contain the particular analytes, PALs, and quantitation limits (QLs). Worksheet #17 provides the rationale for the particular sampling at each area.
   - Four soil samples and one sediment sample will be collected at UXO 15 (**Figure 17**) and analyzed for explosives, perchlorate, metals, and pH.
   - If other debris piles of comparable size are found during the investigation, an additional soil sample will be collected beneath each.
   - If subsurface MEC is identified during the DGM, they will be excavated and soil samples will be collected beneath them in a manner consistent with the approach for any surficial MEC identified.

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

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

- Samples will be collected during one field mobilization planned to occur in January 2011.

- Data will be collected and generated in accordance with the procedures outlined in the UFP-SAP. Specifically, see the SOPs in Appendix A for more details.

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

- CH2M HILL field staff will collect the samples.
- Laboratory analysis will be performed by Katahdin Analytical Services, Inc. of Scarborough, Maine and Test America – West Sacramento for perchlorate.

8. How will the data be archived?

The data will be archived in accordance with procedures dictated in the Navy CLEAN program/contract. At the end of the project, archived data will be returned to the Navy.

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

The decision analysis process shown in **Figure** 5 represents the PQOs for the UXO 15 work in this ESI. The general objectives of the decision analysis process are:

1. To determine if a CERCLA-related release occurred and, if so,
2. Whether the release warrants further investigation or action

The 7-step decision analysis can be subdivided into five PQO categories, as described below.

<u>CERCLA Eligibility (Step 1 of Figure 5)</u>

CERCLA eligibility is determined in general accordance with USEPA guidance (USEPA, 1991, 1999a, and 1999b). The resulting PQO statement is:

> If the site is CERCLA eligible, then collect site-specific samples (if none exist); otherwise, prepare a no further action decision document or defer to another regulatory program.

The decision analysis process potentially applies to all sites initially identified in the Vieques Environmental Restoration Program. For the UXO 15 site included in this SAP, it is assumed that the site is CERCLA-eligible.

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

Data Quality Assessment (Step 2 of Figure 1)

The data quality assessment is performed via the Data Quality Evaluation (DQE) (see Worksheet #37). The resulting PQO statement is:

> If the DQE indicates the data are available and useful for the intended purpose, then perform the release assessment (see Steps 3 and 4); otherwise, collect sufficient additional samples to achieve an available and useful data set.

Release Assessment (Steps 3 and 4 of Figure 1)

The PQO statements for release assessment are:

1. If any inorganics above the background UTL or non-inorganics are detected, then a release potentially occurred; otherwise, make a final evaluation of the adequacy of the data set (see Step 7).
2. If a release potentially occurred, then determine if it is CERCLA-related; otherwise, make a final evaluation of the adequacy of the data set (see Step 7).
3. If a release is CERCLA-related, then determine if the release warrants further action (see Steps 5 and 6); otherwise, make a final evaluation of the adequacy of the data set (see Step 7).

A "CERCLA-related release" is a release of hazardous substances, pollutants, and contaminants eligible for CERCLA response as defined in CERCLA Sections 101(14) and 101(33).

Further Investigation or Action Determination (Steps 5 and 6 of Figure 1)

Once a potential release is suspected, the need for further investigation or action is made by evaluating the data with respect to human health, ecological, leaching, or other regulatory criteria (i.e., Vieques screening values). If additional investigation is warranted, a SAP addendum or a new SAP will be prepared, as appropriate. The PQO statements associated with these steps are:

1. If the constituent concentrations exceed Vieques screening values, then determine if more realistic evaluations can be performed; otherwise (i.e., if no exceedances), make a final evaluation of the adequacy of the data set (see Step 7).
2. If more realistic evaluations can be performed that suggest no further investigation or action is warranted, then make a final evaluation of the adequacy of the data set (see Step 7); otherwise, make a determination of whether additional source data would permit more realistic evaluations.
3. If additional source data would permit more realistic evaluations, then collect the data and make the more realistic evaluations; otherwise, make a determination of whether an interim action or expanded investigation is warranted.

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

4. If interim action is warranted, then perform interim action and collect confirmatory data for evaluation via the decision analysis process; otherwise, make a determination of the type of expanded investigation that is warranted.
5. If the data suggest a substantial release has occurred (e.g., release may be widespread and screening suggests risks are potentially very high with respect to regulatory threshold levels), then perform a Remedial Investigation (RI); otherwise, perform an ESI.

Examples of more realistic evaluations are presented in Section 1.1.2 of the Final PA/SI Report (CH2M HILL, June 2008).

As stated previously, the 7-step decision analysis process applies to the UXO 15 site in the ESI phase. The UXO 15 site which is in the ESI will have additional, related PQOs, as follows:

- One soil sample will be collected beneath each large debris pile, at a minimum from beneath the five aforementioned piles. If other piles of comparable size (approximately 10 feet (ft) x 10 ft) are found during the investigation, an additional soil sample will be collected beneath each. If larger debris piles are found, multiple samples will be collected in comparable increments (i.e., one additional sample per approximate additional 10 ft x 10 ft area of debris. With respect to the interval from which the soil samples will be collected, if the debris or item at a particular location is solely MEC, the soil sample will be collected from the 2-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris or item at a particular location is not or does not contain MEC, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris at a particular location is a mixture of MEC and non-MEC items, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. The samples beneath debris piles A through D are assumed to be soil and the sample beneath debris pile E is assumed to be sediment.
- Soil samples will be collected beneath any MEC items identified and excavated during the DGM investigation at PI 9, PI 13 and the EADAs. The soil samples will be collected from the 2-inch interval beneath the items following their removal.

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SAP Worksheet #12-1 — Measurement Performance Criteria Table

Matrix: Sediment and Surface Soil
Analytical Group: METAL
Concentration Level: Medium (SW-846 6010B) and Low (SW-846-6020, 7196A)

QC Sample[2]	Analytical Group[1]	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Field Duplicate	METAL	One per 10 field samples	Precision	% relative percent difference (RPD) ≤30%	S & A
Equipment Rinseate Blank	METAL	One per day	Bias / Contamination	Same as method blank. Refer to Worksheet 28-1.	S
Temperature Blank	METAL	One per cooler	Accuracy / Representativeness	2-6 degrees Celsius (°C)	S

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

[2] Matrix Spike/Matrix Spike Duplicate (MS/MSD) is described on Worksheet 28.

SAP Worksheet #12-2 — Measurement Performance Criteria Table

Matrix: Sediment and Surface Soil
Analytical Group: EXPLO
Concentration Level: Low (SW-846 8330, 6850)

QC Sample[2]	Analytical Group[1]	Frequency	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
Field Duplicate	EXPLO	One per 10 field samples	Precision	%RPD ≤30%	S & A
Equipment Rinseate Blank	EXPLO	One per day	Bias / Contamination	Same as method blank. Refer to Worksheet 28-2.	S
Temperature Blank	EXPLO	One per cooler	Accuracy / Representativeness	2-6°C	S

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

[2] MS/MSD is described on Worksheet 28.

SAP Worksheet #12-3 — Measurement Performance Criteria Table

Matrix: Sediment and Surface Soil
Analytical Group: WCHEM
Concentration Level: Low (SW-846 9045C)

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	Wet Chemistry (WCHEM)	One per cooler	Accuracy / Representativeness	2-6°C	S

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

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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
Elevated anomaly density areas (EADA)	Expanded Range Assessment/Site Inspection (ERA/SI)	EADAs identified during the ERA/SI using aerial magnetometer survey	Identification of sampling locations	Limited to the accuracy of the device performing the survey. The aerial magnetometer is accurate up to 2 centimeters. Refer to Attachment A Field SOPs (Aerial Magnetometry SOP)
MD, MPPEH, scrap metal item locations	Expanded Range Assessment/Site Inspection (ERA/SI)	MD, MPPEH, scrap metal identified during SIs and associated geophysical surveys	Locations, varieties and concentrations of MD, MPPEH, scrap metal items have been used to locate systematic sampling	Locations of items limited to the accuracy of the PDA used to collect the data. The PDA is accurate up to submeter distances. Refer to PDA GeoExplorer User Guide in Attachment A.

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SAP Worksheet #14 — Summary of Project Tasks for UXO 15

The *Master Standard Operating Procedures, Protocols, and Plans (MSOPPPs)* (CH2M HILL, 2010a) address the protocols and SOPs to be used for the ESI. Specifically, SOPs A-2 and A-3 (Appendix A) provide the protocols and SOPs for soil sampling activities, and SOPs A-3 and G-2 are applicable to sediment sampling activities. The proposed field activities for UXO 15 are discussed below. The technical approach and sample design for the proposed field activities are discussed in Worksheet #17.

Mobilization

Prior to mobilization, NAVFAC Atlantic, USEPA, PREQB, and USFWS will be notified to allow for appropriate oversight and coordination.

As part of the field mobilization, CH2M HILL will procure the following subcontractors to support investigation activities:

- Analytical laboratory
- Data validation
- IDW disposal contractor
- UXO avoidance support
- Excavation contractor to support debris removal and excavation services

Mobilization for the field effort includes procurement of necessary field equipment and initial transport to the site. Equipment and supplies will be brought to the site when the CH2M HILL field team mobilizes for field activities.

Digital Geophysical Mapping

Biological Assessment Prior to Vegetation Clearance

Vegetation removal at UXO 15 is required to support related DGM. A biological assessment (BA) of sensitive species and habitats will be conducted prior to vegetation removal activities. The BA will be conducted throughout sites PI 9 and PI 13 to check for threatened or endangered plants and animals and rare or sensitive habitats. If the explosive safety submission determination (ESSD) is approved by Naval Ordnance Safety and Security Activity (NOSSA), UXO avoidance support for the BA at UXO 15 will not be required.

If possible, the US Fish and Wildlife Service (USFWS) will participate in the planning and field implementation of the BA. This cooperative biological assessment process is intended to more efficiently gain consensus on the species and habitats present and any special considerations that need to be taken during vegetation clearance. A BA report summarizing the findings and consensus between the Navy and USFWS, including site maps, vegetated areas proposed to be cleared, and locations of protected species or habitats within the sites, will be presented to USFWS for review and concurrence. It is anticipated that subsequent vegetation clearance will be conducted in accordance with the Vegetation Clearance SOP for Environmental Investigations contained within the Master Plans (CH2M HILL, 2010a). However, if site-specific observations and consensus indicate modifications to the

SAP Worksheet #14 — Summary of Project Tasks for UXO 15 (continued)

Vegetation Clearance SOP are warranted, the BA report will include the modified clearing methods to be used to minimize (as best as possible considering the purpose of the project) impacts to these sensitive resources.

Vegetation Clearance with UXO Avoidance

Site vegetation clearance activities will begin after USFWS concurrence with the results of the BA. If the ESSD is approved by NOSSA, UXO avoidance support throughout sites PI 9 and PI 13 and the five debris piles will not be required during vegetation clearance.

Considering the site-specific vegetation clearance protocol, an initial reconnaissance of sites PI-9 and PI-13 will be conducted to determine the amount of vegetative material that must be removed to accomplish the scope of work and inspect each site for MEC and non-munitions related debris/ MD on the surface of each site. The team will also map out the areas in which bedrock outcrops will undergo visual inspection, but not DGM. Photographs will be taken of the overall site vegetation, debris found on the surface, and any other notable features. The site-specific vegetation clearance protocol, along with observations, documentation, mapping of outcropping bedrock, and analysis of the density of the vegetation will be used to determine the amount and method of vegetation removal.

It is estimated that vegetation removal will be required for most of the area identified for DGM. Roadways and coastal areas that have already been surveyed will not require additional DGM. In areas where vegetation removal will be conducted mechanically using a bobcat with a hydro-axe attachment or similar piece of machinery (although alternate methods may be employed to achieve the same result), an ESSD will be required. Unless it is necessary, cutting trees larger than 3 inches in diameter will be avoided (unless they are invasive species and their removal enhances DGM). Trees will be felled into an area that has already been surface swept for MEC. The vegetation will typically be cut to a height of approximately 6 inches above ground surface to eliminate interference with anomaly detection or survey activities, and to keep the cutting activities away from the ground surface and possible MEC. All cut vegetation will be accumulated onsite and left at the site to provide mulching for future vegetation.

Following vegetation clearance, a visual survey across PI 9 and PI 13 will be conducted for the removal of any debris identified on the surface to facilitate the DGM survey. The surface clearance of metal debris will be conducted in accordance with the procedures identified in the *Work Plan for Munitions and Explosives of Concern Subsurface Interim Removal Action Beaches and Select Roadways* (CH2M HILL, 2008).

DGM Operations

The DGM survey at the PI 9 and PI 13 sites (**Figure 3**) and two additional areas of high EADA anomalies outside of the PI 9 and PI 13 boundaries will be conducted using an EM61-MK2 time domain electromagnetic metal detector. Areas containing outcropping bedrock will be excluded from the DGM survey because any debris will be at the surface in those areas and will be observed during the visual site inspection. The geophysical operations will be conducted in accordance with Appendix B of the *Expanded Range Assessment/Phase II Site Inspection Work Plan, Former Vieques Naval Training Range, Vieques, Puerto Rico* (CH2M HILL, 2006). FWS and the Navy may identify locations where isolated stands of vegetation, no

SAP Worksheet #14 — Summary of Project Tasks for UXO 15 (continued)

larger than a ½ acre in size, may be left in place to preserve the ecological habitat. Should any of these locations impeded the operation of the DGM, a hand held geophysical instrument, electromagnetic instrument or metal detector will be utilized to delineate the extent of subsurface anomalies.

Excavation of Subsurface Anomalies

The excavation of the geophysical anomalies will be conducted in accordance with the procedures identified in *Work Plan for Munitions and Explosive of Concern Subsurface Interim Removal Action Beaches and Select Roadways* (CH2M HILL, 2008). Positions and information on any sources of anomalies not removed from the subsurface will be recorded, and the reasons for not removing them will be documented in accordance with the *Non-Time Critical Removal Action Work Plan, Surface Munitions and Explosives of Concern at Munitions Response Area-Surface Impact Area Munitions Response Sites 1-7, Former Vieques Naval Training Range (VNTR), Vieques, Puerto Rico* (CH2M HILL, 2009). Reasons for not removing the source of an anomaly include not finding the source (e.g., magnetic spot in bedrock), an object is below the water table and the hole will not remain open to continue excavation, etc. If encountered, these will be recorded in the field logbook and included in the ESI report.

Test pitting of select EADA areas was originally identified in the scoping session held on July 14th and 15th 2010. However, the method employed to identify the EADA is not precise (i.e., does not identify individual anomaly locations). Therefore, DGM will be conducted across PI 9, PI 13, and the EADA locations proposed in the scoping session for test pitting (**Figure 3**). This will improve the efficiency of any excavation since it will be conducted only at locations positively identified by DGM, which can precisely identify the location of subsurface anomalies potentially associated with possible historical trenching and filling (see **Figures 18 thru 21).** Soil samples will be collected beneath any MEC items identified and excavated during the DGM investigation at PI 9, PI 13 and the EADAs. The soil samples will be treated, as applicable considering standard practices, similarly to surface soil samples. These subsurface samples will be collected from the 2-inch interval beneath the items following their removal.

The following documents provide additional explosives management procedures to be conducted during the Preliminary Assessment/ Site Inspection: *Explosives Safety Submission/ Site Approval Request, Former Vieques Naval Training Range (VNTR), Vieques, Puerto Rico (Revision 3)* (CH2M HILL, 2006a) and *Explosives Operations Site Approval, Former Vieques Naval Training Range, Vieques Island, Puerto Rico* (CH2M HILL, 2004a).

QC will be conducted according to Section 10 and Appendix B of the *Work Plan for Munitions and Explosives of Concern Subsurface Interim Removal Action Beaches and Select Roadways* (CH2M HILL, 2008).

Sample Location Mark-out

The sampling locations will be established using Real Time Kinematic (RTK) Global Positioning System (GPS) coordinates, accurate to approximately 2 centimeters, depending on ambient conditions such as canopy cover. Each sampling area and sampling point will be walked by UXO avoidance subcontractors prior to coordinate establishment and sampling for UXO avoidance.

SAP Worksheet #14 — Summary of Project Tasks for UXO 15 (continued)

Debris Pile Removal and offshore Munition Related Debris Removal

As a general housekeeping measure, to remove potential sources of contamination, and to facilitate soil/sediment sampling, the debris piles will be removed and metal items and any munition related debris will be taken to the Central Processing Center (CPC) within the LIA for proper disposal and recycling. All other non hazardous items will be taken to the Vieques landfill for disposal.

In addition, the 32 MD items previously identified during the ERA/SI will be removed during this investigation. The locations of these items are shown in Figure 2.

The near-shore marine environment around Vieques will be addressed as one site; however, the items above the low-tide water level just offshore of PI 9 (**Figures 13 and 14**) will be removed for aesthetic purposes since there will already be a contractor onsite to remove the terrestrial debris piles.

Soil Sampling

Discrete Soil Sample Collection

Four soil samples will be collected, one beneath each large debris pile located in the non-wetland areas of the site shown in **Figure 17** as samples VEUXO15-SS01-MMYY to VEUXO15-SS04-MMYY). If other piles of comparable size are found during the investigation, an additional soil sample will be collected, one beneath each. With respect to the interval from which the soil samples will be collected, if the debris or item at a particular location is solely MEC, the soil sample will be collected from the 2-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris or item at a particular location is not or does not contain MEC, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. If the debris at a particular location is a mixture of MEC and non-MEC items, the soil sample will be collected from the 6-inch interval beneath the debris/item following its (and any suspected contaminated soil) removal. Samples will be collected with a hand auger or similar sampling device in accordance with the Master Protocols.

Sediment Sample Collection

One sediment sample will be collected. This sample will be collected at Debris Pile E shown in **Figure 17** as sample VEUXO15-SD05-MMYY where mangrove swamp is known to exist. From an ecological risk perspective, media collected from beneath this pile would be evaluated as sediment, and therefore a sediment sample, rather than a soil sample, will be collected here.

SAP Worksheet #14 — Summary of Project Tasks for UXO 15 (continued)

Sample Analysis

The discrete soil and sediment samples collected will be homogenized in the field, and then sent to the laboratory in appropriate sample containers for explosives, perchlorate, metals, and general chemistry parameters. Acid volatile sulfide/simultaneously extracted metals (AVS/SEM) and Grain Size are also needed for sediment. Details of the laboratory analysis are included in Worksheet #28 and **Appendix B**.

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

Equipment Decontamination

Equipment decontamination will follow the Master Protocols SOP E-1.

Investigation-Derived Waste Management

IDW will be managed and disposed of in accordance with the Master Waste Management Plan (CH2M HILL 2010a). Liquid and solid IDW will be sampled for Toxicity Characteristic Leaching Procedure (TCLP) and RCI to determine the disposal options. The disposal subcontractor will determine the necessary parameters.

Shipments

All offsite analytical samples will be delivered to the laboratory by FedEx. All samples will be shipped in accordance with the Master SOP 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, field work will be overseen by a field team leader, or his delegate, who is responsible for the quality control of the sampling and make sure the proper SOPs are followed for each task.

Data Management

The Project EIS, Angela Barch, 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 Navy Installation Restoration Information System (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 #15-1 — Reference Limits and Evaluation Table

Matrix: SS
Analytical Group: METAL

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (mg/kg)	Soil TRVs (mg/kg)	Project Quantitation Limit Goal[1,2] (mg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[3]		
						LOQs (mg/kg)	LODs (mg/kg)	DLs (mg/kg)	LCL	UCL	RPD
Aluminum	7429-90-5	6010B	7700	NC	3850	30	10	0.71	80	120	20
Antimony	7440-36-0	6010B	3.1	78	1.55	0.8	0.5	0.070	80	120	20
Arsenic	7440-38-2	6020	0.39	18	0.39	0.5	0.4	0.15	80	120	20
Barium	7440-39-3	6010B	1500	330	165	0.5	0.3	0.026	80	120	20
Beryllium	7440-41-7	6010B	16	40	8	0.5	0.05	0.026	80	120	20
Cadmium	7440-43-9	6010B	7	32	3.5	1	0.3	0.0079	80	120	20
Calcium	7440-70-2	6010B	NC	NC	10	10	8	1.78	80	120	20
Hexavalent Chromium	18540-29-9	7196A	0.29	NC	0.29	0.5	0.25	0.152	85	115	30
Chromium	7440-47-3	6020	0.29	64	0.29	0.3	0.2	0.05	80	120	20
Cobalt	7440-48-4	6010B	2.3	13	1.15	3	0.4	0.029	80	120	20
Copper	7440-50-8	6010B	310	70	35	2.5	1	0.06	80	120	20
Iron	7439-89-6	6010B	5500	NC	2750	10	8	1.4	80	120	20
Lead	7439-92-1	6010B	400	120	60	0.5	0.4	0.087	80	120	20
Magnesium	7439-95-4	6010B	NC	NC	10	10	8	0.68	80	120	20
Manganese	7439-96-5	6010B	180	220	90	0.5	0.4	0.16	80	120	20
Nickel	7440-02-0	6010B	150	38	19	4	0.4	0.044	80	120	20
Potassium	7440-09-7	6010B	NC	NC	100	100	50	2.9	80	120	20
Selenium	7782-49-2	6010B	39	0.52	0.52	1	0.7	0.17	80	120	20
Silver	7440-22-4	6010B	39	560	19.5	1.5	0.4	0.027	80	120	20
Sodium	7440-23-5	6010B	NC	NC	100	100	50	1.5	80	120	20
Thallium	7440-28-0	6020	NC	1	0.5	0.1	0.04	0.0094	80	120	20
Vanadium	7440-62-2	6010B	39	130	19.5	2.5	0.4	0.037	80	120	20
Zinc	7440-66-6	6010B	2300	120	60	2.5	1	0.17	80	120	20

Shading represents cases where the PAL is less than the laboratory LOD. Refer to Worksheet #11 "What are the project action limits" for discussion on how the data will be used and how non-detections at the laboratory LOD will be addressed.

NC: No screening level for this compound. Ca, Mg, K, and Na are nutrients. Although there are no PALs for nutrients, their analysis is useful for determining parent rock material. In addition, inclusion of nutrients can help interpret the other metals results. Soil TRVs for aluminum and iron are based on pH levels and thus are not included on this table. Soil pH levels are considered when determining whether aluminum and iron pose risk to ecological receptors. N/A: Not applicable.

[1] The Project Action Limit for SS is "RSLs Residential Soil Adjusted" (May, 2010) and "Soil TRVs".

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

[3] DoD QSM v. 4.1 is the basis for laboratory control sample (LCS) and MS/MSD limits.

LOQ/LOD/DL are as defined in DoD QSM v. 4.1.

QLs and results for solid samples are presented on a dry weight basis.

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

Matrix: SD
Analytical Group: METAL

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (mg/kg)	SSLs[3] (mg/kg)	Marine Sediment TRVs (mg/kg)	Project Quantitation Limit Goal[1,2] (mg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[4]		
							LOQs (mg/kg)	LODs (mg/kg)	DLs (mg/kg)	LCL	UCL	RPD
Aluminum	7429-90-5	6010B	7700	55000	18000	3850	30	10	0.71	80	120	20
Antimony	7440-36-0	6010B	3.1	0.27	2	0.27	0.8	0.5	0.070	80	120	20
Arsenic	7440-38-2	6020	0.39	0.29	8.2	0.29	0.5	0.4	0.15	80	120	20
Barium	7440-39-3	6010B	1500	82	48	24	0.5	0.3	0.026	80	120	20
Beryllium	7440-41-7	6010B	16	3.2	NC	1.6	0.5	0.05	0.068	80	120	20
Cadmium	7440-43-9	6010B	7	0.38	1.2	0.38	1	0.3	0.0079	80	120	20
Calcium	7440-70-2	6010B	NC	NC	NC	10	10	8	1.78	80	120	20
Hexavalent Chromium	18540-29-9	7196A	0.29	0.00083	NC	0.00083	0.5	0.25	0.152	85	115	30
Chromium	7440-47-3	6020	0.29	180000	81	0.29	0.3	0.2	0.08	80	120	20
Cobalt	7440-48-4	6010B	2.3	0.49	10	0.49	3	0.4	0.029	80	120	20
Copper	7440-50-8	6010B	310	46	34	17	2.5	1	0.06	80	120	20
Iron	7439-89-6	6010B	5500	640	220000	320	10	8	1.4	80	120	20
Lead	7439-92-1	6010B	400	14	46.7	7	0.5	0.4	0.087	80	120	20
Magnesium	7439-95-4	6010B	NC	NC	NC	10	10	8	0.68	80	120	20
Manganese	7439-96-5	6010B	180	57	260	28.5	0.5	0.4	0.16	80	120	20
Nickel	7440-02-0	6010B	150	48	20.9	10.45	4	0.4	0.044	80	120	20

SAP Worksheet #15-1a — Reference Limits and Evaluation Table (continued)

Matrix: SD
Analytical Group: METAL

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (mg/kg)	SSLs[3] (mg/kg)	Marine Sediment TRVs (mg/kg)	Project Quantitation Limit Goal[1,2] (mg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[4]		
							LOQs (mg/kg)	LODs (mg/kg)	DLs (mg/kg)	LCL	UCL	RPD
Potassium	7440-09-7	6010B	NC	NC	NC	100	100	50	2.9	80	120	20
Selenium	7782-49-2	6010B	39	0.26	1	0.26	1	0.7	0.17	80	120	20
Silver	7440-22-4	6010B	39	1.6	1	1	1.5	0.4	0.027	80	120	20
Sodium	7440-23-5	6010B	NC	NC	NC	100	100	50	1.5	80	120	20
Thallium	7440-28-0	6020	NC	0.14	NC	0.14	0.1	0.04	0.0094	80	120	20
Vanadium	7440-62-2	6010B	39	180	57	19.5	2.5	0.4	0.037	80	120	20
Zinc	7440-66-6	6010B	2300	680	150	75	2.5	1	0.17	80	120	20

Shading represents cases where the PAL is less than the laboratory LOD. Refer to Worksheet #11 "What are the project action limits" for discussion on how the data will be used and how non-detections at the laboratory LOD will be addressed.

NC: No screening level for this compound. Ca, Mg, K, and Na are nutrients. Although there are no PALs for nutrients, their analysis is useful for determining parent rock material. In addition, inclusion of nutrients can help interpret the other metals results. N/A: Not applicable.

[1] The Project Action Limit for SD is "RSLs Residential Soil Adjusted" (May, 2010), "SSLs", RSLs Risk-Based SSLs" and "Marine Sediment TRVs".

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

[3] RSLs Risk-Based SSLs were used where no RSLs MCL-Based SSLs were found.

[4] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.

LOQ/LOD/DL are as defined in DoD QSM v. 4.1.

QLs and results for solid samples are presented on a dry weight basis

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

Matrix: SS
Analytical Group: EXPLO (SW-846 8330, 6850)

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (µg/kg)	Soil TRVs (µg/kg)	Project Quantitation Limit Goal[1,2] (µg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[3]		
						LOQs (µg/kg)	LODs (µg/kg)	DLs (µg/kg)	LCL	UCL	RPD
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	8330	380000	10000	5000	100	50	8.6	75	125	20
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	8330	5500	10000	2750	100	50	6.8	70	135	20
1,3,5-Trinitrobenzene (1,3,5-TNB)	99-35-4	8330	220000	NC	110000	100	50	6.7	75	125	20
1,3-Dinitrobenzene (1,3-DNB)	99-65-0	8330	610	NC	305	100	50	6.2	80	125	20
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	479-45-8	8330	24000	10000	10000	100	50	5.4	10	150	20
Nitrobenzene (NB)	98-95-3	8330	4800	2260	2260	100	50	22	75	125	20
2,4,6-Trinitrotoluene (2,4,6-TNT)	118-96-7	8330	3600	10000	1800	100	50	6.7	55	140	20
4-Amino-2,6-dinitrotoluene (4-Am-DNT)	19406-51-0	8330	15000	NC	7500	100	50	17	80	125	20
2-Amino-4,6-dinitrotoluene (2-Am-DNT)	35572-78-2	8330	15000	80000	7500	100	50	21	80	125	20
2,4-Dinitrotoluene (2,4-DNT)	121-14-2	8330	1600	11000	800	100	50	15	80	125	20
2,6-Dinitrotoluene (2,6-DNT)	606-20-2	8330	6100	8500	3050	100	50	27	80	120	20
2-Nitrotoluene (2-NT)	88-72-2	8330	2900	NC	1450	100	50	12	80	125	20
3-Nitrotoluene (3-NT)	99-08-1	8330	610	NC	305	100	50	7.9	75	120	20
4-Nitrotoluene (4-NT)	99-99-0	8330	24000	NC	12000	100	50	27	75	125	20
Pentaerythritol tetranitrate (PETN)	78-11-5	8330	NC	NC	800	800	400	108	30	150	20
Nitroglycerin (NG)	55-63-0	8330	610	NC	610	800	400	124	30	150	20
3,5-Dinitroaniline (3,5-DNA)	618-87-1	8330	NC	NC	100	100	50	4	30	150	20
Perchlorate	14797-73-0	6850	5500	1000	500	5	0.4	0.26	80	120	15

NC: No screening level for this compound. N/A: Not applicable.
[1] The Project Action Limit for SS is "RSLs Residential Soil Adjusted" (May, 2009) and "Soil TRVs".
[2] The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.
[3] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.
DoD QSM v. 4.1 does not provide limits for this compound. In-house limits used.
LOQ/LOD/DL are as defined in DoD QSM v. 4.1.
QLs and results for solid samples are presented on a dry weight basis

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

Matrix: SD
Analytical Group: EXPLO (SW-846 8330, 6850)

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (µg/kg)	SSLs[3] (µg/kg)	Marine Sediment TRVs (µg/kg)	Project Quantitation Limit Goal[1,2] (µg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[4]		
							LOQs (µg/kg)	LODs (µg/kg)	DLs (µg/kg)	LCL	UCL	RPD
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	8330	380000	2300	115000	1150	100	50	8.6	75	125	20
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	8330	5500	0.23	891000	0.23	100	50	6.8	70	135	20
1,3,5-Trinitrobenzene (1,3,5-TNB)	99-35-4	8330	220000	3900	7000	1950	100	50	6.7	75	125	20
1,3-Dinitrobenzene (1,3-DNB)	99-65-0	8330	610	3.3	NC	3.3	100	50	6.2	80	125	20
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	479-45-8	8330	24000	1400	72	72	100	50	5.4	10	150	20
Nitrobenzene (NB)	98-95-3	8330	4800	0.079	21	0.079	100	50	22	75	125	20
2,4,6-Trinitrotoluene (2,4,6-TNT)	118-96-7	8330	3600	13	20000	13	100	50	6.7	55	140	20
4-Amino-2,6-dinitrotoluene (4-Am-DNT)	19406-51-0	8330	15000	56	NC	56	100	50	17	80	125	20
2-Amino-4,6-dinitrotoluene (2-Am-DNT)	35572-78-2	8330	15000	56	NC	56	100	50	21	80	125	20
2,4-Dinitrotoluene (2,4-DNT)	121-14-2	8330	1600	0.29	NC	0.29	100	50	15	80	125	20
2,6-Dinitrotoluene (2,6-DNT)	606-20-2	8330	6100	50	549	50	100	50	27	80	120	20

SAP Worksheet #15-2a — Reference Limits and Evaluation Table (continued)

Matrix: SD

Analytical Group: EXPLO (SW-846 8330, 6850)

Analyte	CAS Number	Analysis Method	RSLs Residential Soil Adjusted (µg/kg)	SSLs[3] (µg/kg)	Marine Sediment TRVs (µg/kg)	Project Quantitation Limit Goal[1,2] (µg/kg)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[4]		
							LOQs (µg/kg)	LODs (µg/kg)	DLs (µg/kg)	LCL	UCL	RPD
2-Nitrotoluene (2-NT)	88-72-2	8330	2900	0.29	NC	0.29	100	50	12	80	125	20
3-Nitrotoluene (3-NT)	99-08-1	8330	610	3.4	NC	3.4	100	50	7.9	75	120	20
4-Nitrotoluene (4-NT)	99-99-0	8330	24000	3.9	NC	3.9	100	50	27	75	125	20
Pentaerythritol tetranitrate (PETN)	78-11-5	8330	NC	NC	NC	800	800	400	108	30	150	20
Nitroglycerin (NG)	55-63-0	8330	610	1.6	NC	1.6	800	400	124	30	150	20
3,5-Dinitroaniline (3,5-DNA)	618-87-1	8330	NC	NC	NC	100	100	50	4	30	150	20
Perchlorate	14797-73-0	6850	5500	NC	NC	2750	5	0.4	0.26	80	120	15

Shading represents cases where the PAL is less than the laboratory LOD. Refer to Worksheet #11 "What are the project action limits" for discussion on how the data will be used and how non-detections at the laboratory LOD will be addressed.

NC: No screening level for this compound. N/A: Not applicable.

[1] The Project Action Limit for SS is "RSLs Residential Soil Adjusted" (May, 2010), "SSLs", RSLs Risk-Based SSLs" and "Marine Sediment TRVs".

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

[3] RSLs Risk-Based SSLs were used where no RSLs MCL-Based SSLs were found.

[4] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.

DoD QSM v. 4.1 does not provide limits for this compound. In-house limits used.

LOQ/LOD/DL are as defined in DoD QSM v. 4.1.

QLs and results for solid samples are presented on a dry weight basis

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

Matrix: SD and SS
Analytical Group: WCHEM

Analyte	CAS Number	Analysis Method	Project Quantitation Limit Goal[1,2]	Laboratory-specific		LCS, MS, and MSD %R and %RPD Limits[3]		
				QLs	MDLs	LCL	UCL	RPD
pH	PH	9045	N/A	N/A	N/A	N/A	N/A	N/A

NC: No screening level for this compound. N/A: Not applicable.
[1] There are no project action limits for these wet chemistry analyses (they are screening data).
[2] The Project Quantitation Limit Goal is 1/2 the PIL, the PIL, or the Laboratory Specific QL, as applicable.
[3] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.
QLs and results for solid samples are presented on a dry weight basis

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

Matrix: AQ (blanks only)
Analytical Group: METAL

Analyte	CAS Number	Analysis Method	Project Quantitation Limit Goal[1,2] (µg/L)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits[3]		
				LOQs (µg/L)	LODs (µg/L)	DLs (µg/L)	LCL	UCL	RPD
Aluminum	7429-90-5	6010B	300	300	100	13	80	120	20
Antimony	7440-36-0	6010B	8	8	5	1.3	80	120	20
Arsenic	7440-38-2	6020	5	5	4	2.2	80	120	20
Barium	7440-39-3	6010B	5	5	4	0.35	80	120	20
Beryllium	7440-41-7	6010B	5	5	0.5	0.091	80	120	20
Cadmium	7440-43-9	6010B	10	10	3	0.12	80	120	20
Calcium	7440-70-2	6010B	100	100	80	6.8	80	120	20
Hexavalent Chromium	18540-29-9	7196A	25	25	12.5	5.4	85	115	20
Chromium	7440-47-3	6020	3	3	2	0.22	80	120	20
Cobalt	7440-48-4	6010B	30	30	2	0.27	80	120	20
Copper	7440-50-8	6010B	25	25	10	0.7	80	120	20
Iron	7439-89-6	6010B	100	100	80	5.2	80	120	20
Lead	7439-92-1	6010B	5	5	4	1	80	120	20
Magnesium	7439-95-4	6010B	100	100	80	9.4	80	120	20
Manganese	7439-96-5	6010B	5	5	4	0.67	80	120	20
Nickel	7440-02-0	6010B	40	40	4	0.24	80	120	20
Potassium	7440-09-7	6010B	1000	1000	400	95	80	120	20
Selenium	7782-49-2	6010B	10	10	7	3	80	120	20
Silver	7440-22-4	6010B	15	15	5	0.79	80	120	20
Sodium	7440-23-5	6010B	1000	1000	500	22	80	120	20
Thallium	7440-28-0	6020	2	2	0.04	0.015	80	120	20
Vanadium	7440-62-2	6010B	25	25	4	0.35	80	120	20
Zinc	7440-66-6	6010B	25	25	12	1.7	80	120	20

NC: No screening level for this compound. Ca, Mg, K, and Na are nutrients. N/A: Not applicable.
[1] There are no project action limits for AQ because these samples are blanks only.
[2] The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.
[3] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.
LOQ/LOD/DL are as defined in DoD QSM v. 4.1.

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

Matrix: AQ
Analytical Group: EXPLO (SW-846 8330, 6850)

Analyte	CAS Number	Analysis Method	Project Quantitation Limit Goal1,2 (µg/L)	Laboratory-specific			LCS, MS, and MSD %R and %RPD Limits3		
				LOQs (µg/L)	LODs (µg/L)	DLs (µg/L)	LCL	UCL	RPD
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0	8330	0.25	0.25	0.125	0.043	80	115	20
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	8330	0.25	0.25	0.125	0.046	50	160	20
1,3,5-Trinitrobenzene (1,3,5-TNB)	99-35-4	8330	0.25	0.25	0.125	0.04	65	140	20
1,3-Dinitrobenzene (1,3-DNB)	99-65-0	8330	0.25	0.25	0.125	0.045	45	160	20
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	479-45-8	8330	0.25	0.25	0.125	0.06	20	175	20
Nitrobenzene (NB)	98-95-3	8330	0.25	0.25	0.125	0.071	50	140	20
2,4,6-Trinitrotoluene (2,4,6-TNT)	118-96-7	8330	0.25	0.25	0.125	0.064	50	145	20
4-Amino-2,6-dinitrotoluene (4-Am-DNT)	19406-51-0	8330	0.25	0.25	0.125	0.053	55	155	20
2-Amino-4,6-dinitrotoluene (2-Am-DNT)	35572-78-2	8330	0.25	0.25	0.125	0.038	50	155	20
2,4-Dinitrotoluene (2,4-DNT)	121-14-2	8330	0.25	0.25	0.125	0.052	60	135	20
2,6-Dinitrotoluene (2,6-DNT)	606-20-2	8330	0.25	0.25	0.125	0.056	60	135	20
2-Nitrotoluene (2-NT)	88-72-2	8330	0.25	0.25	0.125	0.071	45	135	20
3-Nitrotoluene (3-NT)	99-08-1	8330	0.25	0.25	0.125	0.063	50	130	20
4-Nitrotoluene (4-NT)	99-99-0	8330	0.25	0.25	0.125	0.06	50	130	20
Perchlorate	14797-73-0	6850	0.5	0.5	0.25	0.082	80	120	15

NC: No screening level for this compound. N/A: Not applicable.
[1] There are no project action limits for AQ because these samples are blanks only.
[2] The Project Quantitation Limit Goal is 1/2 the PAL, the PAL, or the Laboratory Specific QL, as applicable.
[3] DoD QSM v. 4.1 is the basis for LCS and MS/MSD limits.
DoD QSM v. 4.1 does not provide limits for this compound. In-house limits used.
LOQ/LOD/DL are as defined in DoD QSM v. 4.1.

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SAP Worksheet #16 - Project Schedule / Timeline

The field investigation activities are anticipated to occur in January 2011. The official schedule is the Site Management Plan (SMP) schedule that is distributed and updated separately.

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SAP Worksheet #17 — Sampling Design and Rationale

Given that the scope of work under this SAP is an ESI, the general sampling rationale and design are based on the objective of determining whether a release has occurred and, if so, whether it warrants further action. Based on this objective, the sampling design is based on a judgmental (i.e., biased) approach.

The UXO 15 site has no relevant historical sample data, sample locations are biased to those areas where, if a release occurred (based on known or suspected site historical information and/or field observations), it would most likely be detected via environmental media samples.

For the above sampling approach, the rationale for the matrices to be sampled, the number of samples per matrix, the analytical groups, and the concentration levels is discussed in Worksheets #10, #11, #14, and #15. A sample location figures is provided as **Figure 17**. The following table further identifies the sampling design and rationale.

Matrix	Depth of Samples	Analysis	Method	Number of Samples	Rationale	Sampling Strategy
Surface Soil	6-inch interval below debris[b]	Explosives with perchlorate	SW-846 8330 and 6850 respectively	4[a]	To determine if there has been a release of hazardous substances to underlying medium from debris piles. Sample matrix is based on conceptual understanding of release (i.e., deterioration of debris and leaching into underlying medium). Analytical protocol based on knowledge of past activities and potential debris items (munitions and munitions-related debris). Depth interval based on Vieques debris sampling protocol (as modified when debris is solely munitions).	SOP A-2 and A-3
		Metals and Hexavalent Chromium	SW-846 6010B, 6020, and 7196A	4[a]		
		pH oxidation-reduction potential (ORP) TOC	SW-846 9045C American Society for Testing and Materials (ASTM) D1498-93 Lloyd Kahn	4[a]		
Sediment	2-inch interval below debris[b]	Explosives with perchlorate	SW-846 8330 and 6850 respectively	1[d]	See above	SOP A-3 and G-2
		Metals and Hexavalent Chromium	SW-846 6010B, 6020, 7196A	1[d]		
		AVS/SEM	EPA 821-R-91-100	1[d]		
		Grain Size	ASTM D422	1[d]		
		pH ORP TOC	SW-846 9045C ASTM D1498-93 Lloyd Kahn	1[d]		

SAP Worksheet #17 — Sampling Design and Rationale (continued)

Matrix	Depth of Samples	Analysis	Method	Number of Samples	Rationale	Sampling Strategy
Subsurface Soil	2-inch interval below debris[b]	Explosives with perchlorate	SW-846 8330 and 6850 respectively	TBD[c]	See above	SOP A-2 and A-3
		Metals and Hexavalent Chromium	SW-846 6010B, 6020, and 7196A	TBD[c]		
		pH ORP TOC	SW-846 9045C ASTM D1498-93 Lloyd Kahn	TBD[c]		

[a] Minimum number of samples (1 sample per debris pile or soil); additional samples will be collected if additional debris piles of comparable size are identified

[b] If debris item/pile is solely MEC the depth will be the 2-inch interval below the item. If it does not contain MEC or is a mixture of MEC and non-MEC the depth will be 6-inch interval below item/debris.

[c] Subsurface soil samples will be collected only if subsurface MEC, MEC-containing debris, or potentially hazardous material is identified.

[d] Minimum number of samples (1 sample per debris pile on sediment); additional samples will be collected if additional debris piles of comparable size are identified.

SAP Worksheet #18 — UXO 15 Sampling Locations and Methods/SOP Requirements Table

Station ID	Sample ID	Matrix	Depth (units)	Analytical Group	Number of Samples (identify field duplicates) [2]	Sampling SOP Reference [1]
Debris Piles Samples						
VEUXO15-TAA01	VEUXO15-SS01-06I-MMYY	Surface soil sample	0-6-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1 (including 1 field duplicate for soil sampling activities)	See Worksheet 21
VEUXO15-TAA02	VEUXO15-SS02-06I-MMYY	Surface soil sample	0-6-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21
VEUXO15-TAA03	VEUXO15-SS03-06I-MMYY	Surface soil sample	0-6-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21
VEUXO15-TAA04	VEUXO15-SS04-06I-MMYY	Surface soil sample	0-6-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21
VEUXO15-TAA05	VEUXO15-SD05-02I-MMYY	Sediment sample	0-2-inches bgs	EXPLO, METAL, AVSSEM, GRAINSIZE, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1 (including 1 field duplicate for sediment sampling activities)	See Worksheet 21
Potential MEC Samples						
	VEUXO15-SS06-02I-MMYY	Surface soil sample	0-2-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21
	VEUXO15-SB01-3638I-MMYY	Subsurface soil sample*	36-38-inches bgs	EXPLO, METAL, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21
	VEUXO15-SD07-02I-MMYY	Sediment sample	0-2-inches bgs	EXPLO, METAL, AVSSEM, GRAINSIZE, and WCHEM (pH, ORP, and TOC; see Worksheet 15)	1	See Worksheet 21

[1] SOP or worksheet that describes the sample collection procedures
[2] Other than duplicates, QA/QC samples are not included in this worksheet. Please refer to Worksheet 20 for the required QA/QC samples.
* For any munitions item dug up below 2 feet, sampling will be done at 0-2 inches below the item. This example is for an item found at 3 feet bgs.

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SAP Worksheet #19 — Analytical SOP Requirements Table

Matrix	Analytical Group	Analytical and Preparation Method / SOP Reference[1]	Containers	Sample Volume[2]	Preservation Requirements	Maximum Holding Time[3] (preparation / analysis)
SD	EXPLO	SW-846 8330 / CA-402	8 oz glass jar	30g	Cool to 4°C	14 days / 40 days
		SW-846 6850, WS-LC-0012	4 oz Amber glass jar	1g	Headspace in jar Cool to 4°C	28 days
	METAL	SW-846 6010B, 6020 / CA-605, CA-608, CA-627	8 oz glass jar	2g, 2g	Cool to 4°C	6 months
		SW-846 7196A / CA-625		2.5g		30 days / 24 hours
	WCHEM	SW-846 9045C, ASTM D1498-93, Lloyd Kahn / CA-709, TBD, TBD		25g for pH and ORP, TBD for TOC		28 days (as soon as possible for pH)
	AVSSEM	EPA 821-R-91-100 / TBD	8 oz glass jar	TBD	Do not homogenize. Fill completely. Cool to 4°C	14 days
	GRAINSIZE	ASTM D422 / TBD	8 oz glass jar	N/A	N/A	N/A
SS	EXPLO	SW-846 8330 / CA-402	8 oz glass jar	30g	Cool to 4°C	14 days / 40 days
		SW-846 6850, WS-LC-0012	4 oz Amber glass jar	1g	Headspace in jar Cool to 4°C	28 days
	METAL	SW-846 6010B, 6020 / CA-605, CA-608, CA-627	8 oz glass jar	2g, 2g	Cool to 4°C	6 months
		SW-846 7196A / CA-625		2.5g		30 days / 24 hours
	WCHEM	SW-846 9045C, ASTM D1498-93, Lloyd Kahn / CA-709, TBD, TBD		25g for pH and ORP, TBD for TOC		28 days (as soon as possible for pH)
AQ	EXPLO	SW-846 8330 / CA-402	2 of 1L Amber	1L	Cool to 4°C	7 days / 40 days
		SW-846 6850, WS-LC-0012	1 of 125 milliliter(s) (mL) high-density polyethylene (HDPE)	20 mL	Cool to 4°C	28 days
	METAL	SW-846 6010B, 6020 / CA-605, CA-608, CA-627	1 of 500mL HDPE	100mL, 100mL	HNO_3 to pH < 2; Cool to 4°C	6 months
		SW-846 7196A / CA-625	1 of 250mL HDPE	25 mL	Cool to 4°C	24 hours

[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.
The number and type of sample containers may vary slightly as long as they are acceptable for the analytical procedure(s).

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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[4]	No. of VOA Trip Blanks[4]	No. of PT Samples[3]	Total No. of Samples to Lab
SD	METAL	1	1	1		1			5
	EXPLO	1	1	1		1			5
	WCHEM (pH, ORP, TOC)	1							1
	AVSSEM	1							1
	GRAINSIZE	1							1
SS	METAL	4	1	1		1			8
	EXPLO	4	1	1		1			8
	WCHEM (pH, ORP, TOC)	4							4

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 Batch or Project-specific proficiency testing (PT) samples are optional but highly recommended.

4 See Worksheet #12 for collection frequency.

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SAP Worksheet #21 — Project Sampling SOP References Table

Reference numbers refer to the SOP number in the Master Protocols.

Reference Number	Title, Revision Date and / or Number	Originating Organization of Sampling SOP	Equipment Type	Modified for Project Work? (Y/N)	Comments
SOPs A-2	Soil Sampling	CH2M HILL	Stainless steel hand auger or stainless steel spoons	N	
SOPs A-3	Homogenization of Soil and Sediment Samples	CH2M HILL	Stainless steel spoons/spatulas and pans/bowls	N	
SOPs E-1	Decontamination of Personnel and Equipment	CH2M HILL	Decon equipment	N	
SOPs G-2	Sediment Sampling	CH2M HILL	Sample collection device and sample jars	N	
SOPs H-1	Preparing Field Log Books	CH2M HILL	Log book	N	
SOPs H-4	Chain-of-Custody	CH2M HILL	SOP, tape, custody seals, electronic chain of custody forms	N	
SOPs H-5	Packaging and Shipping Procedures for Samples Not Considered Dangerous Goods	CH2M HILL	SOP	N	
SOPs H-6	Equipment Blank Preparation	CH2M HILL	Sample containers	N	

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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
RTK GPS	N/A	Battery charging, cable inspection and cleaning of display and ports	Positional testing on known survey benchmark	Beginning of each daily survey operation	± 4 in. (24 cm) from surveyed benchmark coordinates	Replace faulty cables, reset location input, repair or replace instrument	Team Leader	Trimble RTK SOP in Attachment A with Trimble specification document.
Schonstedt GA-52Cx	N/A	Battery replacement	Instrument response testing over Industry Standard Object	Beginning of each daily survey operation	Qualitative evaluation of analog instrument response	Repair or replace instrument	MEC Team Leader	See instruction manual in Attachment A.
EM61-MK2	Instrument nulling	Battery charging, cable inspection and cleaning of coils, ports and connections	Instrument Verification Strip	Beginning of project	[1] Qualitative evaluation of instrument response in relation to validated industry values	Repair or replace instrument	Project or Site Geophysicist	See SOP in Attachment A for the EM61-MK2.
			Modified Instrument Verification Strip	Beginning of each daily survey operation	[1] ± 20% of standard item response, after background correction	Repair or replace instrument	DGM Team Leader	
			Static Background/Spike test	Beginning and end of each daily survey operation	[1] ± 20% of standard item response, after background correction	Repair or replace instrument	DGM Team Leader	
			Cable Shake test	Beginning of each daily survey operation	No data spikes	Replace faulty cables, repair or replace instrument or connection ports	DGM Team Leader	

[1] NRL/MR/6110--09-9183 (EM61-MK2 Response of Three Munitions Surrogates)

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SAP Worksheet #23 — Analytical SOP References Table

Lab SOP Number	Title, Revision Date, and / or Number	Date Last Reviewed if not Revised	Definitive or Screening Data	Matrix and Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work?[1] (y/n)
CA-101	Equipment Maintenance, 08/09, Revision 8.	currently in review	N/A	N/A	Various	Katahdin Analytical Services, Inc.	N
CA-402	Determination Of Nitroaromatics And Nitramines By HPLC Method 8330.08/09, Revision 4.	currently in review	Definitive	SS, AQ / EXPLO	HPLC	Katahdin Analytical Services, Inc.	Y[2]
CA-604	Acid Digestion Of Aqueous Samples By USEPA Method 3010 for inductively coupled plasma (ICP) and ICP-MS Analysis of Total or Dissolved Metals, 04/10, Revision 5.		Definitive	AQ / METAL	Block Digester	Katahdin Analytical Services, Inc.	N
CA-605	Acid Digestion Of Solid Samples By USEPA Method 3050 For Metals Analysis By ICP-AES And GFAA, 08/09, Revision 4.	currently in review	Definitive	SS / METAL	Block Digester	Katahdin Analytical Services, Inc.	N
CA-608	Trace Metals Analysis By ICP-AES Using EPA Method 6010, 06/10, Revision 11.		Definitive	SS, AQ / METAL	ICP-AES	Katahdin Analytical Services	N
CA-625	Alkaline Digestion and Subsequent Determination of Hexavalent Chromium In Solid Samples Using EPA SW846 Methods 3060 and 7196, 08/09, Revision 4.	July, 2010	Definitive	SS / METAL	Spectrophotometer	Katahdin Analytical Services, Inc.	N
CA-627	Trace Metals Analysis By ICP-MS Using USEPA Method 6020, 04/10, Revision 7.		Definitive	SS, AQ / METAL	ICP-MS	Katahdin Analytical Services, Inc.	N
CA-709	pH Concentration Measurements In Soil Matrices – SW 846 Method 9045, 06/10, Revision 8.		Screening	SS / WCHEM	pH Meter	Katahdin Analytical Services	N
CA-772	Colorimetric Analysis of Hexavalent Chromium using the Automated Konelab Multiwavelength Photometric Analyzer, 08/09, Revision 1	currently in review	Definitive	AQ / WCHEM	Konelab	Katahdin Analytical Services	N
SD-902	Sample Receipt and Internal Control, 08/09, Revision 8	currently in review	N/A	N/A	N/A	Katahdin Analytical Services, Inc.	N
SD-903	Sample Disposal, 05/09, Revision 4.	August, 2010	N/A	N/A	N/A	Katahdin Analytical Services, Inc.	N
WS-LC-0012	Determination of Perchlorate by Liquid Chromatography Coupled with Tandem Mass Spectrometry (LC/MS/MS) by Method 6850 or 8321 Modified, Rev 5.3, Effective 7/23/2010		Definitive	SS, AQ / EXPLO	HPLC/MS/MS	TestAmerica West Sacramento	N

SOP is currently in-review at time of preparation of this Worksheet. This worksheet was prepared 8/20/10.

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 Please refer to Worksheet 28 for modifications to 8330A.

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SAP Worksheet #24 — Analytical Instrument Calibration Table

Instrument[3]	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
HPLC	Initial Calibration	Instrument receipt, major instrument change, when CV does not meet criteria	5 pt calibration – coefficient of determination ≥ 0.990	Repeat Initial calibration and/or perform necessary equipment maintenance. Check calibration standards. Reanalyze affected data.	Analyst, Supervisor	CA-402
	ICV	Once after initial calibration.	80-120% of True Values	Identify source of problem, correct, repeat calibration, rerun samples.	Analyst, Supervisor	
	Continuing Calibration Verification (CCV)	After every 10 samples; If calibration curve previously analyzed, analyze daily before samples.	80-120% of Expected Values	(1) Evaluate the samples: If the %D > +15% and sample results are < PQL, narrate. If %D > ± 15% only on one channel, narrate. If %D > ± 15% and is likely a result of matrix interference, narrate. Otherwise, reanalyze all samples back to last acceptable CV.	Analyst, Supervisor	
ICP-AES	Initial calibration	At the beginning of each day or if QC is out of criteria.	Two point calibration per manufacturer's guidelines; analytes run at their calibration levels must fall within 95-105% of True Values	Recalibrate and/or perform necessary equipment maintenance. Check calibration standards	Analyst, Supervisor	CA-608
	ICV	Once after each Initial Calibration (ICAL), prior to beginning a sample run.	The %R must be within 90-110% of true value for all analytes.	Do not use results for failing elements unless the ICV > 110% and the sample results are non-detect. Investigate and correct the problem.	Analyst, Supervisor	
	Low-Level Calibration Check Standard	Daily, after one-point ICAL	Within ±20% of true value.	Correct problem, then reanalyze. Flagging criteria are not appropriate. No samples may be analyzed without a valid low-level calibration check standard. Low-level calibration check standard should be less than or equal to the RL.	Analyst, Supervisor	
	CCV	At the beginning and end of each run sequence and every 10 samples	90-110% of True Values	Check problem, recalibrate and reanalyze any samples not bracketed by passing CCVs.	Analyst, Supervisor	
ICP-MS	Tune	Daily prior to calibration	Mass calibration within 0.1 amu of true value, Resolution < 0.9 amu at 10% peak height	Perform necessary equipment maintenance	Analyst, Supervisor	CA-627
	Initial calibration	Daily prior to sample analysis.	4 point calibration plus blank – correlation coefficient ≥ 0.995.	Recalibrate and/or perform necessary equipment maintenance. Check calibration standards	Analyst, Supervisor	
	ICV	Before beginning a sample run.	Recovery within ± 10% of true value.	Do not use results for failing elements, unless ICV >110% and sample result < PQL/RL.	Analyst, Supervisor	
	CCV	At the beginning and end of each run sequence and every 10 samples	90-110% of True Values	Check problem, recalibrate and reanalyze any samples not bracketed by passing CCVs.	Analyst, Supervisor	
	Low-level Calibration Check Standard	At beginning and end of run	80-120% of True Values	Do not use results for failing elements, unless PQL rec.> upper limit and sample result < PQL/RL.	Analyst, Supervisor	
Spectophotometer – (HexCr in SS)	Initial calibration	Daily, prior to sample analysis	8 point calibration; Correlation coefficient ≥ 0.995	Recalibrate and/or perform necessary equipment maintenance. Check calibration standards	Analyst, Supervisor	CA-625
	ICV	Before beginning a sample run.	Value of second source within ±10% of true value.	Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat calibration. Flagging criteria are not appropriate. Problem must be corrected. No samples may be run until calibration has been verified.	Analyst, Supervisor	
	CCV	CV-every 10 samples and at the end of the run	90-110% of True Value	If the CCV fails high, report samples that are <PQL. Recalibrate and/or reanalyze samples back to last acceptable CCV recovery.	Analyst, Supervisor	
Konelab (HexCr in AQ)	Initial calibration	Daily prior to sample analysis.	7 point calibration; Correlation coefficient ≥ 0.995	Recalibrate and/or perform necessary equipment maintenance. Check calibration standards	Analyst, Supervisor	CA-773
	CCV	At beginning and end of each run sequence and every 10 samples	+/- 10% of True Value	If the CCV fails high, report samples that are <PQL. Recalibrate and/or reanalyze samples back to last acceptable CCV recovery.	Analyst, Supervisor	
pH Meter	Initial Calibration	Once per day	± 0.05 pH units for every buffer	If calibration is not achieved, check meter, buffer solutions, and probe; replace if necessary; repeat calibration	Analyst, Supervisor	CA-709

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

Instrument[3]	Calibration Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action (CA)	Person Responsible for CA[2]	SOP Reference[1]
LC/MS/MS	Minimum six-point initial calibration for target analytes, lowest concentration standard at or near the RL	Initial calibration prior to sample analysis	Linear: $r^2 > 0.990$ (r>0.995), b < method detection limit (MDL); Quadratic: $r^2 > 0.995$	Correct problem, then repeat initial calibration	Lab Manager / Analyst	WS-LC-0012
	Second-source calibration verification	Once per five-point initial calibration	Less than 15% difference for target analytes	Correct problem, then repeat. If still fails, repeat initial calibration.	Lab Manager / Analyst	
	Daily calibration verification	Before sample analysis and every 10 samples or every 12 hours, as specified by the method, and at the end of the sequence.	Low-range standard: Perchlorate within ±50% of the true value Mid-range standard: Perchlorate within ±15% of the true value	Correct problem, then repeat. If still fails, repeat initial calibration	Lab Manager / Analyst	
	Initial Calibration Blank and Continuing Calibration Blank (ICB/CCB)	Following ICV/CCVs	No target analyte concentrations above ½ the RL.	Rerun ICB. Isolate and correct problem. Reanalyze associated samples.	Lab Manager / Analyst	
	Interference Check Standard (ICS)	Before sample analysis.	70% -130%	Rerun MCT. If problem still exists, recalibrate.	Lab Manager / Analyst	
	Mass calibration	Instrument must have a valid mass calibration prior to any sample analysis. The mass calibration is updated on an as-needed basis (e.g., QC failures, ion masses show large deviations from known masses, major instrument maintenance is performed, or the instrument is moved).	Mass calibration range must bracket the ion masses of interest without greatly exceeding the range. The most recent mass calibration must be used for an analytical run, and the same mass calibration must be used for all data files in an analytical run. Mass calibration must be verified by acquiring a full scan continuum mass spectrum of a perchlorate stock standard. Perchlorate ions should be within ±0.3 m/z of mass 99, 101, and 107 or their respective daughter ion masses (83, 85, and 89), depending on which ions are quantitated.	If the mass calibration fails, recalibrate. If it still fails, consult manufacturer instructions on corrective maintenance. Flagging criteria are not appropriate. Problem must be corrected. No samples may be analyzed under a failing mass calibration.	Lab Manager / Analyst	
	Internal Standard	Every Calibration Standard	ICAL: Internal Standards (IS) for each standard must be within ± 50% of the average area of the ICAL. ICV, CCV: Within ± 50% of the average area of the ICAL or within ± 50% of the 1st CCV of the run, if the ICAL is not run the same day.	Evaluate the system. Reanalyze/repeat the calibration.	Lab Manager / Analyst	

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.
3 DoD QSM v. 4.1 is the basis for specifications on this table. Specifications are based on the SW-846 method that will be performed. Laboratory SOPs and analytical methods are the basis for pH analysis.

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]
HPLC (EXPLO)	Check and sonicate pump valves as needed. Backflush column as needed. Replace analytical column or guard column as needed. Sonicate and replace solvent with every use. Replace the UV lamp as needed. Check and replace seal-pak as needed	QC standards	Column flow, pressure	Prior to initial calibration and/or as necessary.	Acceptable calibration or CV	Correct the problem and repeat calibration or CV	Analyst, Department Manager	CA-402
ICP-AES	Clean torch assembly and spray chamber when discolored or when degradation in data quality is observed. Clean nebulizer, check argon, replace peristaltic pump tubing as needed. Other maintenance specified in lab Equipment Maintenance SOP.	QC standards	Torch, nebulizer chamber, pump, pump tubing	Prior to initial calibration and as necessary	Acceptable calibration or CCV	Correct the problem and repeat calibration or CCV	Analyst, Department Manager	CA-608
ICP-MS	Clean torch assembly and spray chamber when discolored or when degradation in data quality is observed. Clean nebulizer, check argon, replace peristaltic pump tubing as needed. Other maintenance specified in lab Equipment Maintenance SOP.	QC standards	Torch, nebulizer, spray chamber, pump tubing	Prior to initial calibration and as necessary	Acceptable calibration or CCV	Correct the problem and repeat calibration or CCV	Analyst, Department Manager	CA-627
Spectrophotometer (HexCr in SS)	Clear cuvettes and lense as necessary. Outside calibration annually.	QC standards	Cuvettes, cuvette holder, lenses	As necessary	Acceptable calibration or CCV	Correct the problem and repeat calibration or CCV	Analyst, Department Manager	CA-625
Konelab (HexCr in AQ)	Check and clean segments weekly, clean reagent tubes monthly. Change lamp, change diluent and wash tubes, change mixing paddles and syringes, change dispensing needle, all as needed.	QC standards	Reagent tubes, lamp, wash tubes, paddles, syringes, dispensing needles.	Prior to initial calibration and/or as necessary.	Acceptable calibration or CV	Correct the problem and repeat calibration or CV	Analyst, Department Manager	CA-772
pH meter	Clean probe	QC standards	probe	As necessary	Acceptable calibration or CV	Correct the problem and repeat calibration or CV	Analyst, Department Manager	CA-709
LC/MS/MS	Replace columns as needed, check eluent reservoirs	Sensitivity check	Instrument performance and sensitivity	Daily or as needed	CCV pass criteria	Recalibrate	TestAmerica Chemist	WS-LC-0012

[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 Handling System

Sample Collection, Packaging, And Shipment
Sample Collection (Personnel/Organization): FTL (TBD)/CH2M HILL
Sample Packaging (Personnel/Organization): Sample Processor or Field Team Member (TBD)/CH2M HILL
Coordination of Shipment (Personnel/Organization): Sample Processor or Field Team Member (TBD)/CH2M HILL
Type of Shipment/Carrier: Overnight/FedEx
Sample Receipt And Analysis
Sample Receipt (Personnel/Organization): Sample Receipt Personnel/ Katahdin Analytical Services, Inc.
Sample Custody and Storage (Personnel/Organization): Sample Receipt Personnel/ Katahdin Analytical Services, Inc.
Sample Preparation (Personnel/Organization): Extractions Personnel/ Katahdin Analytical Services, Inc.
Sample Determinative Analysis (Personnel/Organization): Analyst/ Katahdin Analytical Services, 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.
Biological Sample Storage (No. of days from sample collection): N/A
Sample Disposal
Personnel/Organization: Environmental Health and Safety Office/ Katahdin Analytical Services, 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 that they do not separate. The following exceptions apply:

- 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. Standard sample nomenclature for blind field duplicates includes a "P" after the station identifier.

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 FTL. 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 received by the laboratory. The chain of custody (COC) will also be placed in 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. See SOP H-4 for details regarding use of custody seals.

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

See the laboratory sample handling SOP: SD-902 "Sample Receipt and Internal Control" 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 require preservative, the clerk will check the pH values to see if these 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 PM for Laboratory Information Management Systems (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 COC. 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

COCs 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 COC will also have the sampler's name and signature. The COC 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: SD, SS
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
METALs by SW-846 6010B						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).
Calibration Blank	Before beginning a sample run, after every 10 samples, and at the end of the analysis sequence.	No analytes detected > LOD.	Correct problem. Re-prep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed. Apply B-flag to all results for specific analyte(s) in all samples associated with the blank.	Analyst	Accuracy/Bias, Contamination	No analytes detected > LOD.
ICS	At the beginning of an analytical run.	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.	Terminate analysis; locate and correct problem; reanalyze ICS; reanalyze all samples. If corrective action fails, apply Q-flag to all results for specific analyte(s) in al samples associated with the ICS.	Analyst	Accuracy/Bias	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-1. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-1. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. If the matrix spike falls outside of DoD criteria, additional quality control tests are required to evaluate matrix effects. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-1.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-1.
Serial Dilution	One per preparatory batch.	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.	Perform post-digestion spike (PDS) addition.	Analyst	Accuracy	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.
PDS	When dilution test fails or analyte concentration in all samples < 50X LOD. *When MS/MSD fails.*	75-125%R	Run all associated samples in the preparatory batch by method of standard additions (MSA). Or, for the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy	75-125%R

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

Matrix: SD, SS
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
METALs by SW-846 6020						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).
Calibration Blank	Before beginning a sample run, after every 10 samples, and at the end of the analysis sequence.	No analytes detected > LOD.	Correct problem. Re-prep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed. Apply B-flag to all results for specific analyte(s) in all samples associated with the blank.	Analyst	Accuracy/Bias, Contamination	No analytes detected > LOD.
(ICS-A and ICS-AB)	At the beginning of an analytical run and every 12 hours.	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.	Terminate analysis; locate and correct problem; reanalyze ICS; reanalyze all samples. If corrective action fails, apply Q-flag to all results for specific analyte(s) in al samples associated with the ICS.	Analyst	Accuracy/Bias	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-1. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-1. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. If the matrix spike falls outside of DoD criteria, additional quality control tests are required to evaluate matrix effects. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-1.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-1.
Serial Dilution	One per preparatory batch.	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.	Perform PDS addition.	Analyst	Accuracy	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.
IS	Every sample.	IS intensity within 30-120% of intensity of the IS in the ICAL.	Reanalyze sample at 5-fold dilution with addition of appropriate amounts of internal standards. Flagging criteria are not appropriate.	Analyst	Accuracy	IS intensity within 30-120% of intensity of the IS in the ICAL.
PDS	When dilution test fails or analyte concentration in all samples < 50X LOD. *When MS/MSD fails.*	75-125%R	Run all associated samples in the preparatory batch by MSA. Or, for the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy	75-125%R

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

Matrix: SD, SS
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Hexavalent Chromium by SW-846 7196A						
Method Blank	One per batch of 20 samples or fewer	Abs. value < 1/2 PQL	Investigate source of contamination. If blank value > PQL report sample results if < PQL or > 10 x the blank value. Otherwise reprep	Analyst, Supervisor, QA Manager	Accuracy / Bias / Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. See Box D-1 of DoD QSM v 4.1.
Calibration Blank	Following each CCV (at beginning of run, after every 10 samples, and at end of run).	Absolute value of CCB < PQL	1) Do not use results if > PQL. 2) Investigate and correct problem.	Analyst, Supervisor, QA Manager	Accuracy / Bias / Contamination	Absolute value of CCB < PQL
Laboratory Control Sample (LCS)	One per digestion batch of 20 samples or fewer	80 -120 %R	If the LCS fails high, report samples that are <PQL. Recalibrate and/or reanalyze other samples.	Analyst, Supervisor, QA Manager	Accuracy / Bias	No analytes detected > LOD.
Sample Duplicate	One sample duplicate per prep batch.	RPD ≤ 30 % for samples > 3X the PQL and <100% for samples < 3X the PQL.	Investigate problem and reanalyze sample in duplicate. If RPD still >20, report original result with notation or narration.	Analyst, Supervisor, QA Manager	Accuracy / Bias / Precision	Refer to Worksheet 15-1. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Pre-digestion Matrix Spike (MS)	One soluble and one insoluble MS per batch of 20 or fewer samples.	75-125 % Recovery if sample conc. < 4 x spike	Correct problem and rehomogenize, redigest, and reanalyze samples. If that fails, evaluate against LCS results. If corrective action fails, apply J-flag to the analyte in all samples in the associated preparatory batch.	Analyst, Supervisor, QA Manager	Accuracy / Bias	Same as LCS.
Post-digestion Matrix Spike (MS)	One per prep batch.	85-115 %R	Narrate.	Analyst, Supervisor, QA Manager	Accuracy / Bias	Same as MS and refer to Worksheet 15-1.

[1]DoD QSM v. 4.1 is the basis for specifications on this table.

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SAP Worksheet #28-2 — Laboratory QC Samples Table

Matrix: SD, SS
Analytical Group: EXPLO
Analytical Method / SOP Reference: SW-846 8330, 6850 / CA-402, WS-LC-0012

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
EXPLO by SW-846 8330						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. (see Box D-1 of DoD QSM v 4.1).
Laboratory Control Sample (ground)	One per preparatory batch. Can be laboratory-prepared or certified reference material	A solid reference material containing all reported analytes must be prepared (e.g., ground and subsampled) and analyzed in exactly the same manner as a field sample. In-house laboratory control limits for the LCS must demonstrate the laboratory's ability to meet the project's measurement quality objectives.	Same as LCS (below)	Analyst	Accuracy/Bias	Same as LCS (below)
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-2 Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-2 Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Surrogate Spike	All field and QC Samples	1,2-Dinitrobenzene: 30-150%	For QC and field samples, correct problem then reprep and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary. Apply Q-flag to all associated analytes if acceptance criteria are not met.	Analyst	Accuracy	1,2-Dinitrobenzene: 30-150%
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. Contact the client as to additional measures to be taken. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-2.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-2.
Confirmation analysis	All field and QC samples.	All samples with positive results	Peaks within the retention time window for the compound on both columns.	Analyst	Accuracy / Precision	All samples with positive results
Soil Preparation (applies only to 8330B-list analytes)						
Sample collection	Each field sample	Field samples are typical discreet field samples. However, the 8330B-list fraction shall be collected into a separate 8oz jar (see Worksheet #19)	No corrective action needed	Field Team Leader	Representativeness	No MPC needed.
Soil drying procedure	Each sample and batch LCS	As per method SW-846 8330B Section 11.1.4.1. Laboratory must have a procedure to determine when the sample is dry to constant weight. Record date, time, and ambient temperature on a daily basis while drying samples.	No corrective action needed	Analyst	Accuracy	No MPC needed.

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

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Sample Grinding Procedure	Each sample and batch LCS	The entire 8330B-list fraction (approximately 8oz) will be hand-ground using mortar and pestle to pass a 10 mesh grain size. Mechanical (mortar and pestle) grinding is also appropriate, but all samples must be treated in a consistent manner.	No corrective action needed	Analyst	Accuracy	No MPC needed.`
Soil grinding blank	Between each sample	A grinding blank using clean solid matrix (such as Ottawa sand) must be prepared (e.g., ground and subsample) and analyzed in the same manner as a field sample. Grinding blanks can be analyzed individually or composited. No target analytes detected greater than ½ RL.	All blank results must be reported and the affected samples must be flagged accordingly if blank criteria are not met. If the composite grinding blank exceeds the acceptance criteria, apply B-flag to all samples associated with the grinding composite. If any individual grinding blank is found to exceed the acceptance criteria, apply B-flag to the sample following that blank.	Analyst	Accuracy/Bias/Contamination	A grinding blank using clean solid matrix (such as Ottawa sand) must be prepared (e.g., ground and subsample) and analyzed in the same manner as a field sample. Grinding blanks can be analyzed individually or composited. No target analytes detected greater than ½ RL.
Soil subsampling process	Each sample and batch QC	Entire ground sample is mixed, spread out on a large flat surface (e.g., baking tray, butcher paper, or aluminum foil), and 30 or more randomly located increments are removed from the entire depth to sum an aliquot for extraction.	No corrective action needed	Analyst	Accuracy	No MPC needed.
Perchlorate (SW-846 6850)						
Method Blank	One per preparation batch	No target analytes ≥ ½ RL in accordance with DoD QSM requirements	Correct problem, then re-extract and reanalyze method blank and all samples processed with the contaminated blank in accordance with DoD QSM requirements	Lab Manager / Analyst	Accuracy/Bias Contamination	No target analytes ≥ ½ RL in accordance with DoD QSM requirements
IS	During acquisition of calibration standard, samples, and QC check samples	Areas within -50% to +100% of the midpoint of the last ICAL for each sample and QC in accordance with DoD QSM requirements	Inspect LCMS for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning in accordance with DoD QSM requirements	Lab Manager / Analyst	Accuracy/Bias	Areas within -50% to +100% of the midpoint of the last ICAL for each sample and QC in accordance with DoD QSM requirements
Limit of Detection Verification (LODV) (per batch)	Prior to sample analysis and at the end of the analysis sequence. It can be analyzed after every 10 samples in order to reduce the reanalysis rate.	Within ±30% of true value.	Correct problem and rerun LODV and all samples analyzed since last successful LODV. If a sample with perchlorate concentration at or between the LOD and RL is bracketed by a failing LODV, it must be reanalyzed. A sample with concentration above the RL can be reported. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable LODV. Problem must be corrected. Results may not be reported without a valid LODV. Flagging is only appropriate in cases where the samples cannot be reanalyzed.	Analyst	Accuracy	Within ±30% of true value.
Interference Check Sample	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.	Within ±30% of true value.	Correct problem and then reanalyze all samples in that batch. If poor recovery from the cleanup filters is suspected, a different lot of filters must be used to re-extract all samples in the batch. If column degradation is suspected, a new column must be calibrated before the samples can be reanalyzed. Flagging criteria are not appropriate. Analysis of a standard containing perchlorate at the RL and interfering anions at the concentration determined by the interference threshold study. Monitor recovery of perchlorate and retention time. No samples may be reported that are associated with a failing ICS.	Analyst	Accuracy	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.

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

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Isotope Ratio	Every Sample and QC	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.	If criteria are not met, the sample must be rerun. If the sample was not pretreated, the sample should be re-extracted using cleanup procedures. If, after cleanup, the ratio still fails, use alternative techniques to confirm presence of perchlorate (i.e., a post spike sample, dilution to reduce any interference, etc.). Apply J-flag if acceptance criteria are not met. Decision to report data failing ratio check should be thoroughly documented in case narrative.	Lab Manager / Analyst	Qualitative Identification	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.
Internal Standard	Addition of ^{18}O-labeled perchlorate to every sample, batch QC sample, standard, instrument blank, and method blank.	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. relative retention times (RRT) of the perchlorate ion must be 1.0±2% (0.98-1.02).	Rerun the sample at increasing dilutions until the ±50% acceptance criteria are met. If criteria cannot be met with dilution, the interference are suspected and the sample must be reprepped using additional pretreatment steps. Apply Q-flag and discuss in the case narrative. If peak is not within retention time window, presence is not confirmed. Use for quantitation and to ensure identification. Failing internal standard should be thoroughly documented in the case narrative.	Analyst	Accuracy/Bias	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. RRT of the perchlorate ion must be 1.0±2% (0.98- 1.02).
LCS	One LCS per analytical/preparation batch	QC acceptance criteria: 80% to 120% accuracy,15% precision; or laboratory statistically derived control limits,	Correct problem, then re-extract and reanalyze the LCS and all associated batch samples in accordance with DoD QSM requirements.	Lab Manager / Analyst	Accuracy/Bias	QC acceptance criteria: 80% to 120% accuracy,15% precision; or laboratory statistically derived control limits,
Matrix Spike	One per prep batch of twenty or fewer samples of similar matrix	Same as LCS	Examine the project specific DQOs. Evaluate the data, and re-prepare/reanalyze the native sample and MS/MSD pair as indicated.	Lab Manager / Analyst	Accuracy/Bias	Same as LCS
Matrix Spike Duplicate	One per prep batch of twenty or fewer samples of similar matrix	Same as MS. RPD ≤ 15%	Same as MS	Lab Manager / Analyst	Accuracy/Bias, Precision	Same as MS. RPD ≤ 15%

[1] DoD QSM v. 4.1 is the basis for specifications on this table.

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SAP Worksheet #28-3 — Laboratory QC Samples Table

Matrix: SD, SS
Analytical Group: WCHEM
Analytical Method / SOP Reference: SW-846 9045C / CA-709

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
pH (SW-846 9045C)						
Laboratory Replicate	One per batch or every 10 samples	%RPD ≤20%	Advisory. Reanalysis may be done unless obvious matrix issues.	Analyst, Laboratory Supervisor	Accuracy, Bias	%RPD ≤20%
Laboratory Control Sample	One per batch or every 20 samples	90-110% recovery	recalibrate	Analyst, Laboratory Supervisor	Accuracy	90-110% recovery

[1] Laboratory SOPs are the basis for specifications on this table.

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SAP Worksheet #28-4 — Laboratory QC Samples Table

Matrix: AQ
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
METALs by SW-846 6010B						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).
Calibration Blank	Before beginning a sample run, after every 10 samples, and at the end of the analysis sequence.	No analytes detected > LOD.	Correct problem. Re-prep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed. Apply B-flag to all results for specific analyte(s) in all samples associated with the blank.	Analyst	Accuracy/Bias, Contamination	No analytes detected > LOD.
ICS	At the beginning of an analytical run.	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.	Terminate analysis; locate and correct problem; reanalyze ICS; reanalyze all samples. If corrective action fails, apply Q-flag to all results for specific analyte(s) in al samples associated with the ICS.	Analyst	Accuracy/Bias	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-4. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-4. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. If the matrix spike falls outside of DoD criteria, additional quality control tests are required to evaluate matrix effects. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-4.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-4.
Serial Dilution	One per preparatory batch.	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.	Perform PDS addition.	Analyst	Accuracy	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.
PDS	When dilution test fails or analyte concentration in all samples < 50X LOD.	75-125%R	Run all associated samples in the preparatory batch by MSA. Or, for the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy	75-125%R

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

Matrix: AQ
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
METALs by SW-846 6020						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. For common laboratory contaminants, no analytes detected > RL (see Box D-1 of DoD QSM v 4.1).
Calibration Blank	Before beginning a sample run, after every 10 samples, and at the end of the analysis sequence.	No analytes detected > LOD.	Correct problem. Re-prep and reanalyze calibration blank. All samples following the last acceptable calibration blank must be reanalyzed. Apply B-flag to all results for specific analyte(s) in all samples associated with the blank.	Analyst	Accuracy/Bias, Contamination	No analytes detected > LOD.
(ICS-A and ICS-AB)	At the beginning of an analytical run and every 12 hours.	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.	Terminate analysis; locate and correct problem; reanalyze ICS; reanalyze all samples. If corrective action fails, apply Q-flag to all results for specific analyte(s) in al samples associated with the ICS.	Analyst	Accuracy/Bias	ICS-A: Absolute value of concentration for all non-spiked analytes < LOD (unless they are a verified trace impurity from one of the spike analytes) ICS-AB: Within ±20% of true value.
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. If the matrix spike falls outside of DoD criteria, additional quality control tests are required to evaluate matrix effects. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-5.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-5.

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

Matrix: AQ
Analytical Group: METAL
Analytical Method / SOP Reference: SW-846 6010B, 6020, 7196A / CA-608, CA-625, CA-627

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Serial Dilution	One per preparatory batch.	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.	Perform PDS addition.	Analyst	Accuracy	Five-fold dilution must agree within ±10% of the original measurement. Only applicable for samples with concentrations > 50X LOQ.
IS	Every sample.	IS intensity within 30-120% of intensity of the IS in the ICAL.	Reanalyze sample at 5-fold dilution with addition of appropriate amounts of internal standards. Flagging criteria are not appropriate.	Analyst	Accuracy	IS intensity within 30-120% of intensity of the IS in the ICAL.
PDS	When dilution test fails or analyte concentration in all samples < 50X LOD.	75-125%R	Run all associated samples in the preparatory batch by MSA. Or, for the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy	75-125%R
Hexavalent Chromium by SW-846 7196A						
Method Blank	One per prep batch	No analyte detected >PQL	(1) Investigate source of contamination.0(2) Report all sample results <PQL. (3) Report sample results >10X the blank result and flag results with a "B". (4) Reanalyze all other samples associated with the failing blank.	Analyst, Laboratory Supervisor	Bias/Contamination	No analyte detected >PQL
Calibration Blank	Following each CCV (at beginning of run, after every 10 samples, and at end of run).	Absolute value of CCB < PQL	1) Do not use results if > PQL. 2) Investigate and correct problem.	Analyst, Laboratory Supervisor	Bias/Contamination	Absolute value of CCB < PQL
Laboratory Control Sample (LCS)	One per prep batch	80-120% recovery	(1) If the LCS fails high, report samples that are <PQL. (2) Recalibrate and/or reanalyze other samples.	Analyst, Laboratory Supervisor	Accuracy, Bias	80-120% recovery
Matrix Spike	One for every set of 10 samples	75-125% recovery	(1) Evaluate the samples and associated QC: i.e. If the LCS results are acceptable, narrate. (2) If both the LCS and MS are unacceptable reprep and reanalyze the samples and QC. (3) Notate sample result in raw data if matrix interference suspected.	Analyst, Laboratory Supervisor	Accuracy/Bias	75-125% recovery
Sample Duplicate	One sample duplicate per ten samples	RPD ≤ 20 for samples >3X the PQL and <100 RPD for samples <3X the PQL.	(1) Investigate problem and reanalyze sample in duplicate. (2) If RPD still out, report original result with notation or narration.	Analyst, Laboratory Supervisor	Precision	RPD ≤ 20 for samples >3X the PQL and <100 RPD for samples <3X the PQL.

[1] DoD QSM v. 4.1 is the basis for specifications on this table.

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SAP Worksheet #28-5 — Laboratory QC Samples Table

Matrix: AQ
Analytical Group: EXPLO
Analytical Method / SOP Reference: SW-846 8330, 6850 / CA-402, WS-LC-0012

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
EXPLO by SW-846 8330						
Method Blank	One per preparatory batch.	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. (see Box D-1 of DoD QSM v 4.1).	Correct problem, then see criteria in Box D-1 of DoD QSM v. 4.1. If required, reprep and reanalyze method blank and all samples processed with the contaminated blank. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply B-flag to all results for the specific analytes(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias, Contamination	No analytes detected > 1/2 RL and > 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. (see Box D-1 of DoD QSM v 4.1).
Laboratory Control Sample	One per preparatory batch.	Refer to Worksheet 15-5 Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	A solid reference material containing all reported analytes must be prepared (e.g., ground and sub sampled) and analyzed in exactly the same manner as a field sample. In-house laboratory control limits for the LCS must demonstrate the laboratory's ability to meet the project's MQOs.
Surrogate Spike	All field and QC samples.	1,2-Dinitrobenzene: 30-150%	For QC and field samples, correct problem then reprep and reanalyze all failed samples for failed surrogates in the associated preparatory batch, if sufficient sample material is available. If obvious chromatographic interference with surrogate is present, reanalysis may not be necessary. Apply Q-flag to all associated analytes if acceptance criteria are not met.	Analyst	Accuracy	1,2-Dinitrobenzene: 30-150%
Matrix Spike	One per preparatory batch per matrix.	Same as LCS.	Examine the project-specific DQOs. Contact the client as to additional measures to be taken. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Same as LCS.
Matrix Spike Duplicate	One per preparatory batch per matrix.	Same as MS and refer to Worksheet 15-5.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-5.
Confirmation analysis	All field and QC samples.	All samples with positive results	Peaks within the retention time window for the compound on both columns.	Analyst	Accuracy / Precision	Peaks within the retention time window for the compound on both columns.
Perchlorate by SW-846 6850						
Method Blank	One per preparatory batch.	No perchlorate detected > ½ RL and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results. quantitation limit	If associated detects are < QL, the results will be reported and the contamination will be narrated. If associated detects > QL, the batch will be re-extracted and reanalyzed.	Analyst	Accuracy/Bias, Contamination	No perchlorate detected > ½ RL and greater than 1/10 the amount measured in any sample or 1/10 the regulatory limit (whichever is greater). Blank result must not otherwise affect sample results.

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

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Limit of detection verification (LODV) (per batch)	Prior to sample analysis and at the end of the analytical sequence. It can be analyzed after every 10 samples in order to reduce the reanalysis rate.	Within ±30% of true value.	Correct problem and rerun LODV and all samples analyzed since last successful LODV. If a sample with perchlorate concentration at or between the LOD and RL is bracketed by a failing LODV, it must be reanalyzed. A sample with concentration above the RL can be reported. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to all results for the specific analyte(s) in all samples since the last acceptable LODV. Problem must be corrected. Results may not be reported without a valid LODV. Flagging is only appropriate in cases where the samples cannot be reanalyzed.	Analyst	Accuracy	Within ±30% of true value.
Laboratory Control Sample	One per preparatory batch. LCS must be spiked at the RL.	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Correct problem, then reprep and reanalyze the LCS and all samples in the associated preparatory batch for failed analytes, if sufficient sample material is available. Refer to Appendix G of DoD QSM v. 4.1. If reanalysis cannot be performed, data must be qualified and explained in the case narrative. Apply Q-flag to specific analyte(s) in all samples in the associated preparatory batch.	Analyst	Accuracy/Bias	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike	One per preparatory batch per matrix. The MS must be spiked at the RL	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.	Examine the project-specific DQOs. Contact the client as to additional measures to be taken. For the specific analyte(s) in the parent sample, apply J-flag if acceptance criteria are not met.	Analyst	Accuracy/Bias	Refer to Worksheet 15-5. Limits are as per DoD QSM v. 4.1. In-house statistical laboratory limits are provided when DoD QSM v. 4.1 does not specify.
Matrix Spike Duplicate	One per preparatory batch per matrix. The MS must be spiked at the RL	Same as MS and refer to Worksheet 15-5.	Same as MS	Analyst	Accuracy/Bias, Precision	Same as MS and refer to Worksheet 15-5.
Interference Check Sample	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.	Within ±30% of true value.	Correct problem and then reanalyze all samples in that batch. If poor recovery from the cleanup filters is suspected, a different lot of filters must be used to re-extract all samples in the batch. If column degradation is suspected, a new column must be calibrated before the samples can be reanalyzed. Flagging criteria are not appropriate. Analysis of a standard containing perchlorate at the RL and interfering anions at the concentration determined by the interference threshold study. Monitor recovery of perchlorate and retention time. No samples may be reported that are associated with a failing ICS.	Analyst	Accuracy	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.
Isotope ratio $^{35}Cl/^{37}Cl$	Every sample, batch QC sample, and standard.	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.	If criteria are not met, the sample must be rerun. If the sample was not pretreated, the sample should be re-extracted using cleanup procedures. If, after cleanup, the ratio still fails, use alternative techniques to confirm presence of perchlorate (i.e., a post spike sample, dilution to reduce any interference, etc.). Apply J-flag if acceptance criteria are not met. Decision to report data failing ratio check should be thoroughly documented in case narrative.	Analyst	Accuracy	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.
Internal Standard	Addition of ^{18}O-labeled perchlorate to every sample, batch QC sample, standard, instrument blank, and method blank.	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. RRT of the perchlorate ion must be 1.0±2% (0.98-1.02).	Rerun the sample at increasing dilutions until the ±50% acceptance criteria are met. If criteria cannot be met with dilution, the interference are suspected and the sample must be reprepped using additional pretreatment steps. Apply Q-flag and discuss in the case narrative. If peak is not within retention time window, presence is not confirmed. Use for quantitation and to ensure identification. Failing internal standard should be thoroughly documented in the case narrative.	Analyst	Accuracy/Bias	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. RRT of the perchlorate ion must be 1.0±2% (0.98- 1.02).

[1] DoD QSM v. 4.1 is the basis for specifications on this table.

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

Matrix: AQ
Analytical Group: EXPLO
Analytical Method / SOP Reference: SW-846 8330, 6850 / CA-402, WS-LC-0012

QC Sample[1]	Frequency / Number	Method / SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Interference Check Sample	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.	Within ±30% of true value.	Correct problem and then reanalyze all samples in that batch. If poor recovery from the cleanup filters is suspected, a different lot of filters must be used to re-extract all samples in the batch. If column degradation is suspected, a new column must be calibrated before the samples can be reanalyzed. Flagging criteria are not appropriate. Analysis of a standard containing perchlorate at the RL and interfering anions at the concentration determined by the interference threshold study. Monitor recovery of perchlorate and retention time. No samples may be reported that are associated with a failing ICS.	Analyst	Accuracy	Once ICS is prepared with every batch of 20 samples and must undergo the same preparation and pretreatment steps as the samples in the batch. It verifies the method performance at the matrix conductivity threshold (MCT). At least one ICS must be analyzed daily.
Isotope ratio $^{35}Cl/^{37}Cl$	Every sample, batch QC sample, and standard.	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.	If criteria are not met, the sample must be rerun. If the sample was not pretreated, the sample should be re-extracted using cleanup procedures. If, after cleanup, the ratio still fails, use alternative techniques to confirm presence of perchlorate (i.e., a post spike sample, dilution to reduce any interference, etc.). Apply J-flag if acceptance criteria are not met. Decision to report data failing ratio check should be thoroughly documented in case narrative.	Analyst	Accuracy	Monitor for either the parent ion at masses 99/101 or the daughter ion at masses 83/85 depending on which ions are quantitated. Theoretical ratio ~3.06. Must fall within 2.3 to 3.8.
Internal Standard	Addition of ^{18}O-labeled perchlorate to every sample, batch QC sample, standard, instrument blank, and method blank.	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. RRT of the perchlorate ion must be 1.0±2% (0.98-1.02).	Rerun the sample at increasing dilutions until the ±50% acceptance criteria are met. If criteria cannot be met with dilution, the interference are suspected and the sample must be reprepped using additional pretreatment steps. Apply Q-flag and discuss in the case narrative. If peak is not within retention time window, presence is not confirmed. Use for quantitation and to ensure identification. Failing internal standard should be thoroughly documented in the case narrative.	Analyst	Accuracy/Bias	Measured ^{18}O IS area within ±50% of the value from the average of the IS area counts of the ICAL. RRT of the perchlorate ion must be 1.0±2% (0.98- 1.02).

[1] DoD QSM v. 4.1 is the basis for specifications on this table.

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SAP Worksheet #29 — Project Documents and Records Table

Document	Where Maintained
Field Notebooks	Electronic portable document format (.pdf) copies in the project file. Hardcopy (bound notebook) in the project file. Archived at project closeout at a private storage facility*.
Chain-of-Custody Records	Electronic. pdf copies in the project file. Hardcopy in the data validation report. Archived at project closeout at a private storage facility*.
Air Bills	Hardcopy in the project file. Archived at project closeout at a private storage facility*.
Telephone Logs	Hardcopy in the project file. Archived at project closeout at a private storage facility*.
Corrective Action Forms	Electronic. pdf copies in the project file. Hardcopy in the project file. Archived at project closeout at a private storage facility*.
All field equipment calibration information	Recorded in Field Notebooks which are archived at project closeout at a private storage facility*.
Pertinent telephone conversations	Recorded in Field Notebook Notebooks which are archived at project closeout at a private storage facility*.
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[1].
Standard Traceability Logs	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Equipment Calibration Logs	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Sample Prep Logs	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Run Logs	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Equipment Maintenance, Testing, and Inspection Logs	Kept on file at the laboratory. Not maintained.
Reported Field Sample Results	Electronic. pdf copies in the project file. Hardcopy in the data package. Archived at project closeout at a private storage facility*.
Reported Results for Standards, QC Checks, and QC Samples	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Chromatograms Before and After Manual Integration	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Brief Explanation for Manual Integration (when required)	Included with the case narrative.

SAP Worksheet #29 — Project Documents and Records Table (continued)

Document	Where Maintained
Instrument Printouts (raw data) for Field Samples, Standards, QC Checks, and QC Samples	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Data Package Completeness Checklists	Hardcopy in the data validation report. Archived at project closeout at a private storage facility*.
Sample Disposal Records	Maintained by the laboratory.
Extraction/Clean-up Records	Maintained by the laboratory.
Raw Data	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Field Sampling Audit Checklists	Hardcopy in the project file. Archived at project closeout at a private storage facility*.
Fixed Laboratory Audit Checklists	If completed, hardcopy in the project file. Archived at project closeout at a private storage facility*.
Data Validation Reports	Electronic. pdf copies in the project file. Hardcopy stored with the data package. Archived at project closeout at a private storage facility*.
Vieques ERP Master Health and Safety Plan	Hardcopy in office and field, maintained during project duration.
UXO 15 Site Specific HASP	Hardcopy in office and field, maintained during project duration.
Manual Integration Documentation	Hardcopy in the full data package[1]. Archived at project closeout at a private storage facility*.
Expanded Site Inspection Report for UXO 15	Electronic. pdf copies in the project file. Hardcopy (bound notebook) in the project file. Archived at project closeout*. at a private storage facility*. Also maintained at the Navy Document library[2]

* Data archiving will be done by CH2M HILL and data will be stored at a private storage facility for approximately 10 years.

1 The format of the full hardcopy data package is described in lab SOPs. CH2M HILL requires a "Level 4" package which generally includes a case narrative, chain of custody, Form 1: Results, Form 2: Surrogates or System Monitoring Compounds, Form 3: MS/MSD or LCS, Form 4: Method Blanks (summary), Form 5: Instrument Performance Check or Tuning, Form 6: Initial Calibration, Form 7: Continuing Calibration, Form 8: Internal Standards, and Raw Data.

2 Expanded Site Inspection Report for UXO 15 will be kept at the Navy Document library and maintained by Bonnie Capito (NAVFAC Atlantic).

CH2M HILL Project Office:
John Swenfurth/CH2M HILL
4350 West Cypress Street #600
Tampa, FL 33607-4155
(813) 874-6522

Archival Location:
Iron Mountain Records Management
4555 Progress Road
Norfolk, VA 23502

SAP Worksheet #30 -- Analytical Services Table

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)
SD	METAL	1	Metals by SW-846 6010B Metals by SW-846 6020 Hexavalent Chromium by SW-846 7196A	28 Calendar-day turnaround time (TAT)	Katahdin Analytical Services, Inc. 600 Technolory Way Scarborough, ME 04074 Ms. Kelly Perkins (207) 874-2400	TBD
	EXPLO		Explosives by SW-846 8330			
			Perchlorate by SW-846 6850		Test America West Sacramento Laboratory 880 Riverside Parkway West Sacramento, CA 95605 Nilo Ligi (916) 374-4427	
	WCHEM		pH by SW-846 9045C ORP by ASTM D1498-93 TOC by Lloyd Kahn		Katahdin Analytical Services, Inc.	
	AVSSEM		AVS/SEM by EPA 821-R-91-100			
	GRAINSIZE		Grain Size (sieve-only, no hydrometer) by ASTM D422		TBD	
SS	METAL	4	Metals by SW-846 6010B Metals by SW-846 6020 Hexavalent Chromium by SW-846 7196A	28 Calendar-day TAT	Katahdin Analytical Services, Inc. 600 Technolory Way Scarborough, ME 04074 Ms. Kelly Perkins (207) 874-2400	TBD
	EXPLO		Explosives by SW-846 8330			
			Perchlorate by SW-846 6850		Test America West Sacramento Laboratory 880 Riverside Parkway West Sacramento, CA 95605 Nilo Ligi (916) 374-4427	
	WCHEM		pH by SW-846 9045C ORP by ASTM D1498-93 TOC by Lloyd Kahn		Katahdin Analytical Services, Inc.	

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

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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	TBD Field auditor 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	TBD Field auditor CH2M HILL	Project Field Team CH2M HILL	Mark Orman H&S Officer CH2M HILL	Mark Orman H&S Officer CH2M HILL
Offsite Laboratory Technical Systems Audit	As necessary (DoD ELAP Letter indicates Expiration)	External	DoD ELAP Accrediting Body	DoD ELAP Accrediting Body	Kelly Perkins/Katahdin PM Nilo Ligi/Test America – West Sacramento PM	Kelly Perkins/Katahdin PM Nilo Ligi/Test America – West Sacramento PM	Anita Dodson/CH2M HILL Program Chemist

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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)	SWO 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.
Offsite Laboratory Technical Systems Audit	Written audit report from DoD ELAP Accrediting Body	Kelly Perkins/Katahdin Nilo Ligi/Test America – West Sacramento	Within 2 Months of Audit	Memorandum	DoD ELAP Accrediting Body	Within 2 months of receipt of initial notification

Note: If a particular deviation from the SAP will prevent the objectives defined herein from being met, the regulatory agencies will be notified as soon as an alternative approach has been considered between the Navy and CH2M HILL.

SAP Worksheet #32-1 — Corrective Action Form

Person initiating CA

Date

Description of problem and when identified:

Cause of problem, if known or suspected:

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

CA implemented by:

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, Activity Hazard Analysis (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 Included in project files.
Data Validation Reports	Once, after analysis by laboratory, for all laboratory analytical data except WCHEM.	Submitted by the data validator within 14 calendar-days of notification to begin)	Project Manager: Laura Maschoff/DataQual Environmental Services	Project Chemist: Michael Zamboni/CH2M HILL Project EIS: Angela Barch/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[1]	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	Field Team Leader (TBD)/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 / External	Field Team Leader (TBD)/CH2M HILL Project EIS: Angela Barch/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.	External	Project EIS: Angela Barch/CH2M HILL
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: Mike Zamboni/CH2M HILL
Case Narrative	Case narratives will be reviewed by the data validator during the data validation process. This is verification that they were generated and applicable to the data packages.	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.	Internal	Laboratory QA Officer
Laboratory Data	The data will be verified for completeness by an EIS specialist.	External	Project EIS: Angela Barch/CH2M HILL
Validation Changes	Validation qualifiers are applied to the electronic deliverable prior to loading in the database. A 100% check on data validation changes (between the hardcopy data validation report and electronic deliverable) is performed by the project chemist.	Internal	Data Validation Subcontractor: Laura Maschoff/DataQual and the Project Chemist: Mike Zamboni/CH2M HILL
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.	External	Project Manager: John Swenfurth/CH2M HILL Project Chemist: Michael Zamboni/CH2M HILL

[1]Internal / External is with respect to the data generator.

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

Step IIa / IIb	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 as per Worksheet 15.	Project Chemist: Michael Zamboni/CH2M HILL
IIb	RLs	Ensure the laboratory met the project-designated quantitation limits as per Worksheet 15. If quantitation limits were not met, the reason will be determined and documented.	Project Chemist: Michael Zamboni/CH2M HILL
IIa	Laboratory SOPs	Ensure that approved analytical laboratory SOPs were followed.	Data Validation Subcontractor: Laura Maschoff/DataQual
IIa / IIb	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.	Data Validation Subcontractor: Laura Maschoff/DataQual
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 (TBD)
IIa	Documentation of Method QC Results	Establish that all required QC samples were run and met limits.	Data Validation Subcontractor: Laura Maschoff/DataQual
IIb	Documentation of field QC Sample Results	Establish that all required QAPP QC samples were run and met limits.	Project Chemist: Michael Zamboni/CH2M HILL Data Validation Subcontractor: Laura Maschoff/DataQual

[1] IIa=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	Validation Criteria	Data Validator (title and organizational affiliation)
IIa and IIb	SD, SS	EXPLO[1]	For SW-846 8330: "Nitroaromatics and Nitroamines by HPLC"; SOP HW-16 Revision 2; September, 2006. Note that this document is specific to SW-846 8330A and the data validator will use the QC limits specified in this UFP-SAP such that the data validation guidance is applicable to SW-846 8330. For SW-846 6850: Analytical methods and laboratory SOPs, as presented in this UFP-SAP, will be used to evaluate compliance against QA/QC criteria. QA/QC criteria for field QC samples are presented in Worksheet 12, QLs and PALs are presented in Worksheet 15, QA/QC criteria for calibrations are presented in Worksheet 24, and QA/QC criteria for laboratory QC samples are presented in Worksheet 28. Data may be qualified if QA/QC exceedances have occurred. Data qualifiers will be those typical to EPA Region II.	Data Validation Subcontractor: Laura Maschoff/DataQual
		METAL[1]	Analytical methods and laboratory SOPs, as presented in this UFP-SAP, will be used to evaluate compliance against QA/QC criteria. QA/QC criteria for field QC samples are presented in Worksheet 12, QLs and PALs are presented in Worksheet 15, QA/QC criteria for calibrations are presented in Worksheet 24, and QA/QC criteria for laboratory QC samples are presented in Worksheet 28. Data may be qualified if QA/QC exceedances have occurred. Data qualifiers will be those presented in "Evaluation of Metals Data for the Contract Laboratory Program (CLP)"; SOP HW-2 Rev.13, ILM05.3; September, 2006. Guidance and qualifiers from USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (EPA, October, 2004) may also be applicable.	
IIa and IIb	SD and/or SS	WCHEM, AVSSEM, and GRAINSIZE	WCHEM, AVSSEM, and GRAINSIZE data will not undergo third-party data validation. However, they are still subject to the verification and validation procedures specified in Worksheets 34 and 35. The case narratives will be read, any issues will be investigated, and the impact (if any) on data quality or data usability will be discussed with the project team.	Project Chemist: Michael Zamboni/CH2M HILL

[1] 100% of EXPLO and METAL data will be third-party validated. Of the 100% validated, the third-party data validator will also recalculate 10% of results from the raw data. The data validator considers manual integration.

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SAP Worksheet #37 — Usability Assessment

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 nature and extent of contamination, the comprehensive dataset will be reviewed to determine if it is adequate for making the project-specific determinations.

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 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.

SAP Worksheet #37 — Usability Assessment (continued)

- 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.
- Data usability is not decided upon by any one individual or entity. The project team, as a whole, will decide upon the usability of the data.
- 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.
- Precision is assessed via percent difference or relative percent difference. Percent difference is typically used when one value is considered theoretically correct and relative percent difference is typically used when both values are experimental. Percent difference is calculated by taking the absolute value of the difference divided by the theoretical value. This is also expressed as

  $$((|X_1 - X_2|) / X_1) * 100$$

  where X_1 is the theoretical value and X_2 is the experimental value. If it is necessary to imply the direction of a bias, such as for percent drift, the absolute value need not be considered. Relative percent difference is calculated by taking the absolute value of the difference divided by the mean. This is also expressed as

  $$((|X_1 - X_2|) / ((X_1 + X_2)/2)) * 100$$

  where X_1 and X_2 are both measured values. Percent difference and relative percent difference often have upper control limits for precision.

SAP Worksheet #37 — Usability Assessment (continued)

- Accuracy is assessed via percent recovery. This is calculated by taking the measured value divided by the theoretical value. This is also expressed as

  $$(X_2 / X_1) * 100$$

  where X_1 is the theoretical value and X_2 is the experimental value, both positive numbers because they are 'amounts' or concentrations. Percent recovery can be negative, such as for MS and MSD recovery, if X_2 is calculated by subtracting a parent concentration from an experimental recovery. Percent recovery often has upper and lower control limits for accuracy.

- Completeness is calculated by taking the number of available results divided by the total number of results. This is also expressed as

  $$(X_2 / X_1) * 100$$

  where X_2 is the number of distinct results deemed "available for use" (not rejected) and X_1 is the total number of distinct results (not excluded). Completeness is calculated for the entire data set, for each matrix, and for each combination of matrix and analysis group. If patterns of rejection are evident in the data set, completeness may also be calculated for select combinations of matrix, analysis group, and analyte or other combinations as applicable for the data quality evaluation. Completeness has a lower control limit (completeness goal) and cannot exceed 100%.

Notes:

1. 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.
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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DoD QSM v. 4.1 is located at www.navylabs.navy.mil/QSM Version 4.1.pdf

Figures

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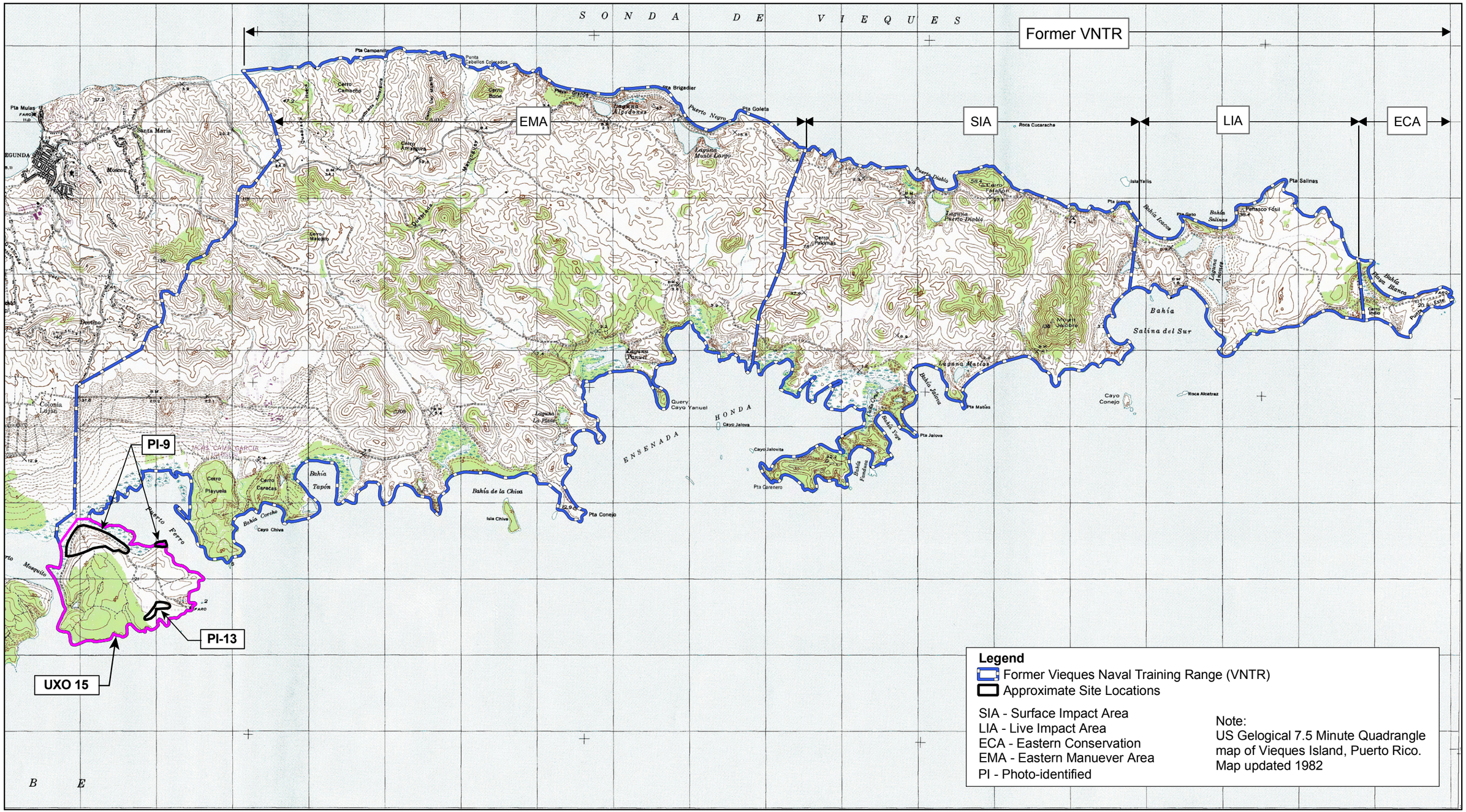


FIGURE 1
Former VNTR Site Location Map
UXO 15 - Expanded Site Inspection
Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\408040_UXO_15_Expanded_Site_Inspection\Figure_3_Location_of_Transect_Items.mxd

Legend

- Non-Munitions-Related Scrap Metal
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Transect
- PI SIte
- UXO Site

Note:
Number next to item indicates the quantity of Item.

N
W E
S

0 350 700 1,400 Feet

Figure 2
Location of Transect Items
UXO 15 - Expanded Site Inspection Sampling and Analysis Plan
Vieques, Puerto Rico

2007 Aerial Photo

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\408040_UXO_15_Expanded_Site_Inspection\Figure_5_Aerial_and_Hand_Held_Magnetometer_Survey_Results.mxd

Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- PI SIte
- Elevated Anomaly Density Area (EADA)
- Area of Digital Geophysical Mapping

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

North

0 350 700 1,400 Feet

Figure 3

Aerial and Hand Held Magnetometer Survey Results

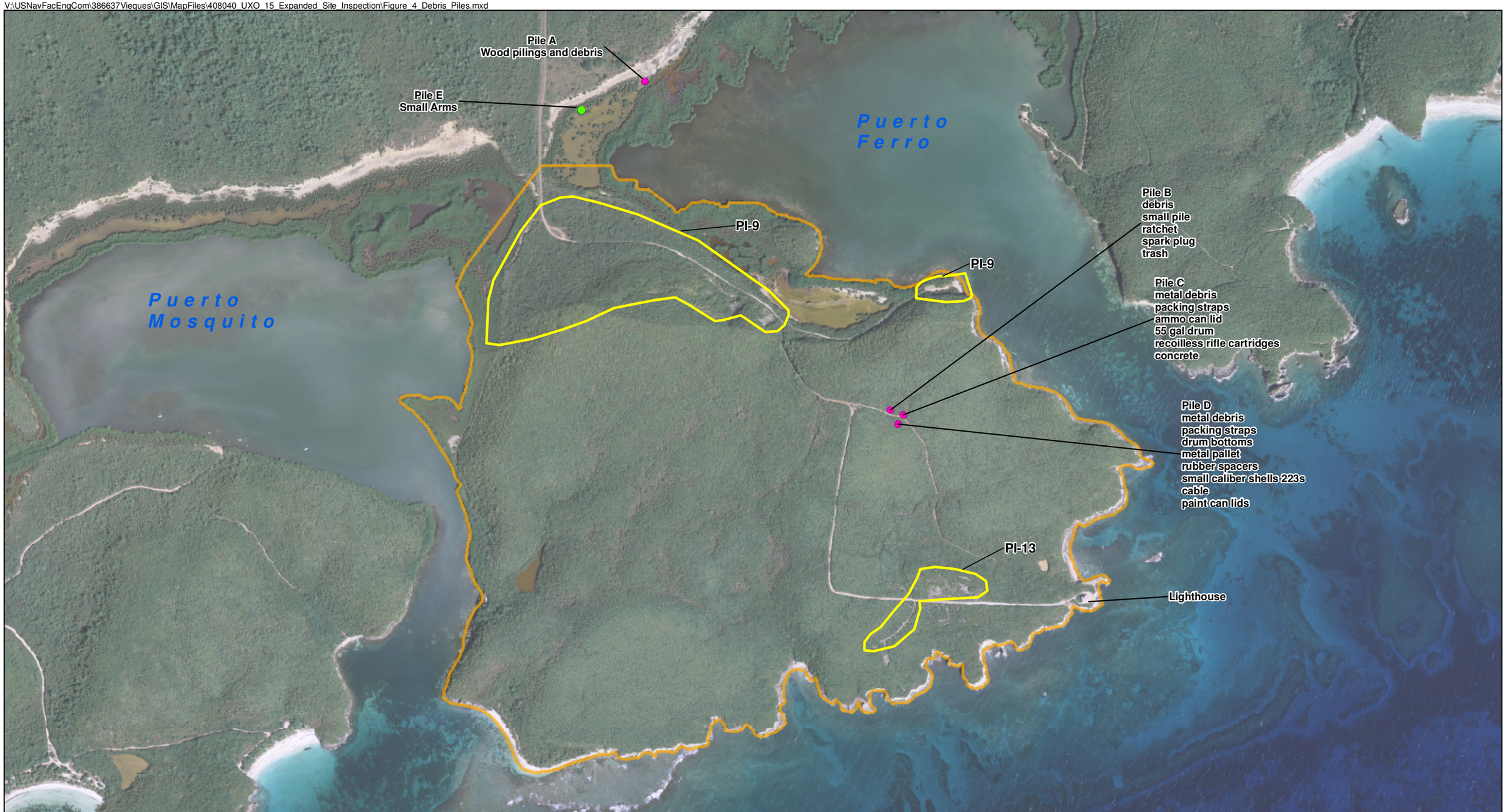
UXO 15 - Expanded Site Inspection Sampling and Analysis Plan

Vieques, Puerto Rico

2007 Aerial Photo

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\408040_UXO_15_Expanded_Site_Inspection\Figure_4_Debris_Piles.mxd



Legend
- Debris Pile and Proposed Soil Sample Location
- Small Arms Pile and Proposed Sediment Sample Location
- PI SIte
- UXO Site

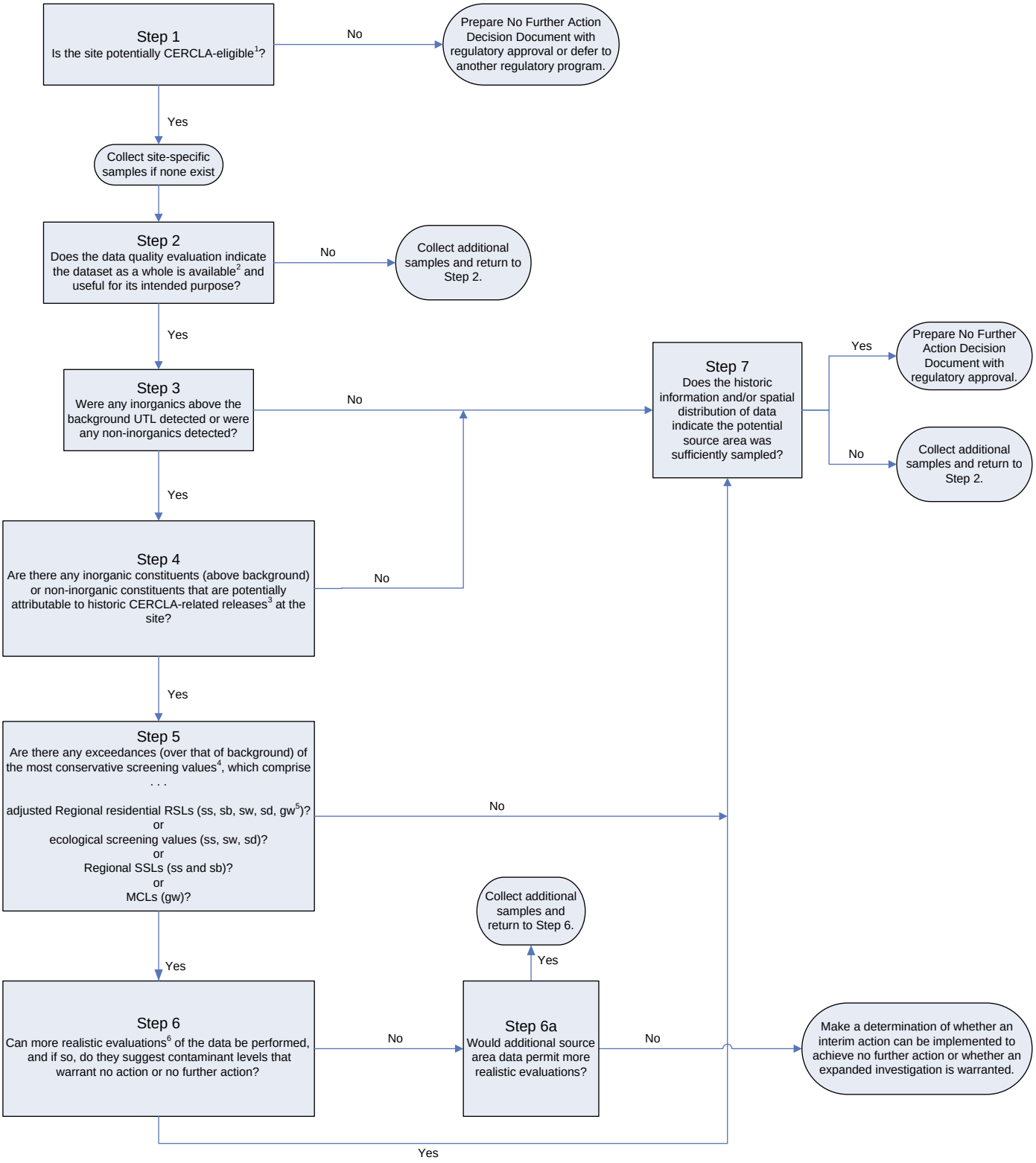
N
W E
S

0 425 850 1,700
Feet

Figure 4
Debris Piles
UXO 15 - Expanded Site Inspection Sampling and Analysis Plan
Vieques, Puerto Rico

2007 Aerial Photo

CH2MHILL



Notes:
The decision makers associated with this decision tree are the Navy, USEPA, PREQB, and USFWS.
[1] Determination of CERCLA eligibility is described in Section 1 of the SI/ESI Report (August 2010)
[2] "Available" data are described in Section 1 of the SI/ESI Report (August 2010)
[3] CERCLA-related releases are defined in Section 1 of the SI/ESI Report (August 2010)
[4] For UST sites, PREQB Land Pollution Control Corrective Action Levels
[5] ss = surface soil; sb = subsurface soil; sw = surface water; sd = sediment; gw = groundwater
[6] Examples of the types of more realistic evaluations that may be performed are described in Section 1 of the SI/ESI Report (August 2010)

FIGURE 5
Expanded SI Evaluation Decision Tree
UXO 15 - Expanded Site Inspection
Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

Figure 6 “Pile A” Wood pilings and debris

Figure 7 “Pile B” Trash

Figure 8 “Pile C” Empty 55 gallon drum and metal straps

Figure 9 “Pile C” Recoilless rifle cartridge and metal straps

Figure 10 “Pile D” Metal straps

Figure 11 “Pile D” Small caliber empty shells with metal straps

Figure 12 “Pile E”

Figure 13 2003 Photo of rusted artillery casings near PI-9

Figure 14 2003 Photo of rusted artillery casings at boat ramp of PI-9

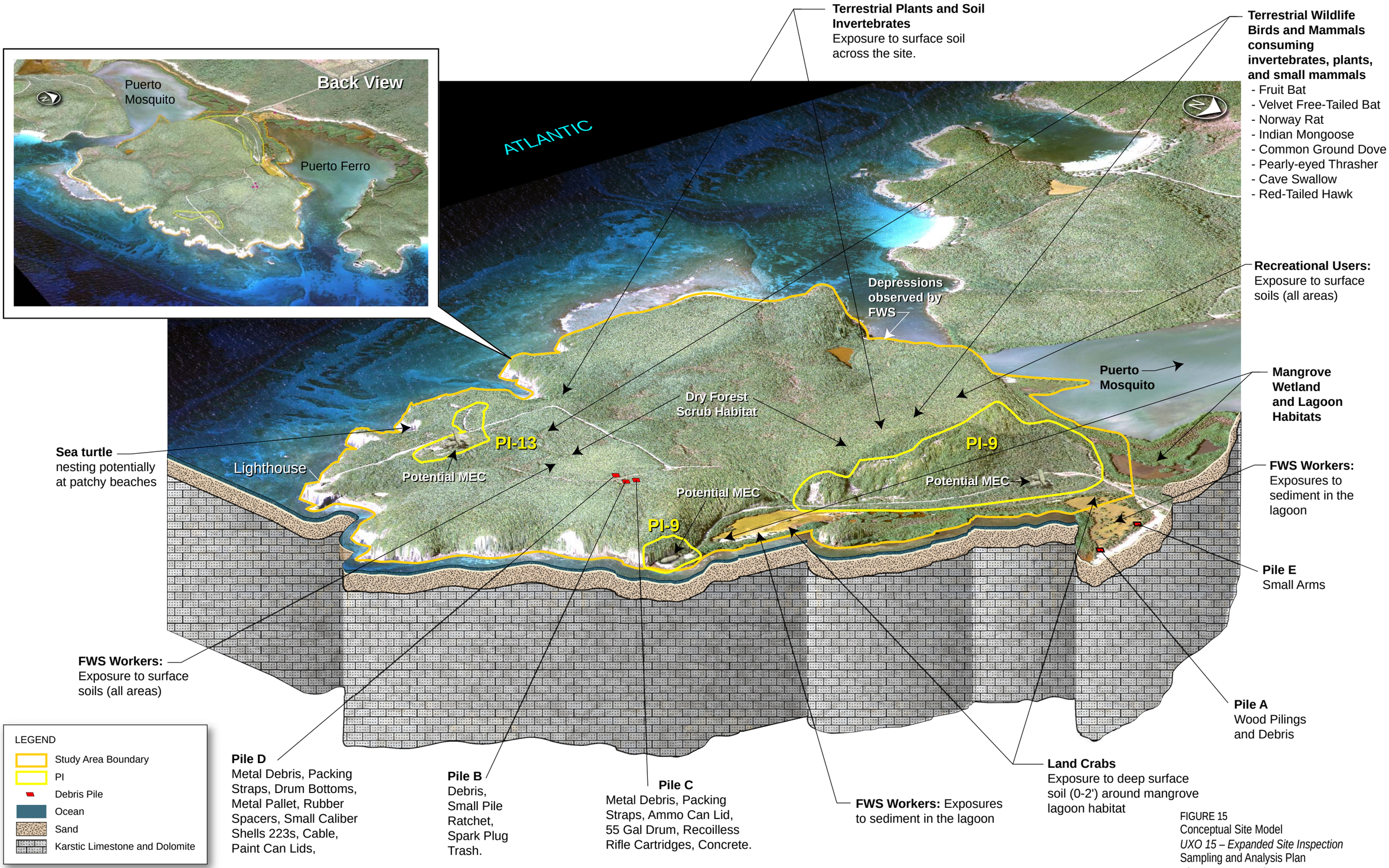


FIGURE 15
Conceptual Site Model
UXO 15 – Expanded Site Inspection
Sampling and Analysis Plan
Vieques, Puerto Rico

CH2MHILL

ES090110063538TPA 1000-CTO-03_Fig-X_Envir_Invest_CSM.ai 09-01-2010 LED

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\408040_UXO_15_Expanded_Site_Inspection\Figure_6_Topographic_Map_USGS.mxd

Legend

Topographic Contour (USGS)

- 1 Meter Interval
- 10 Meter Interval
- PI SIte
- UXO Site

Notes:
Topographic Contours from USGS.
USGS contours are mean sea level.

North

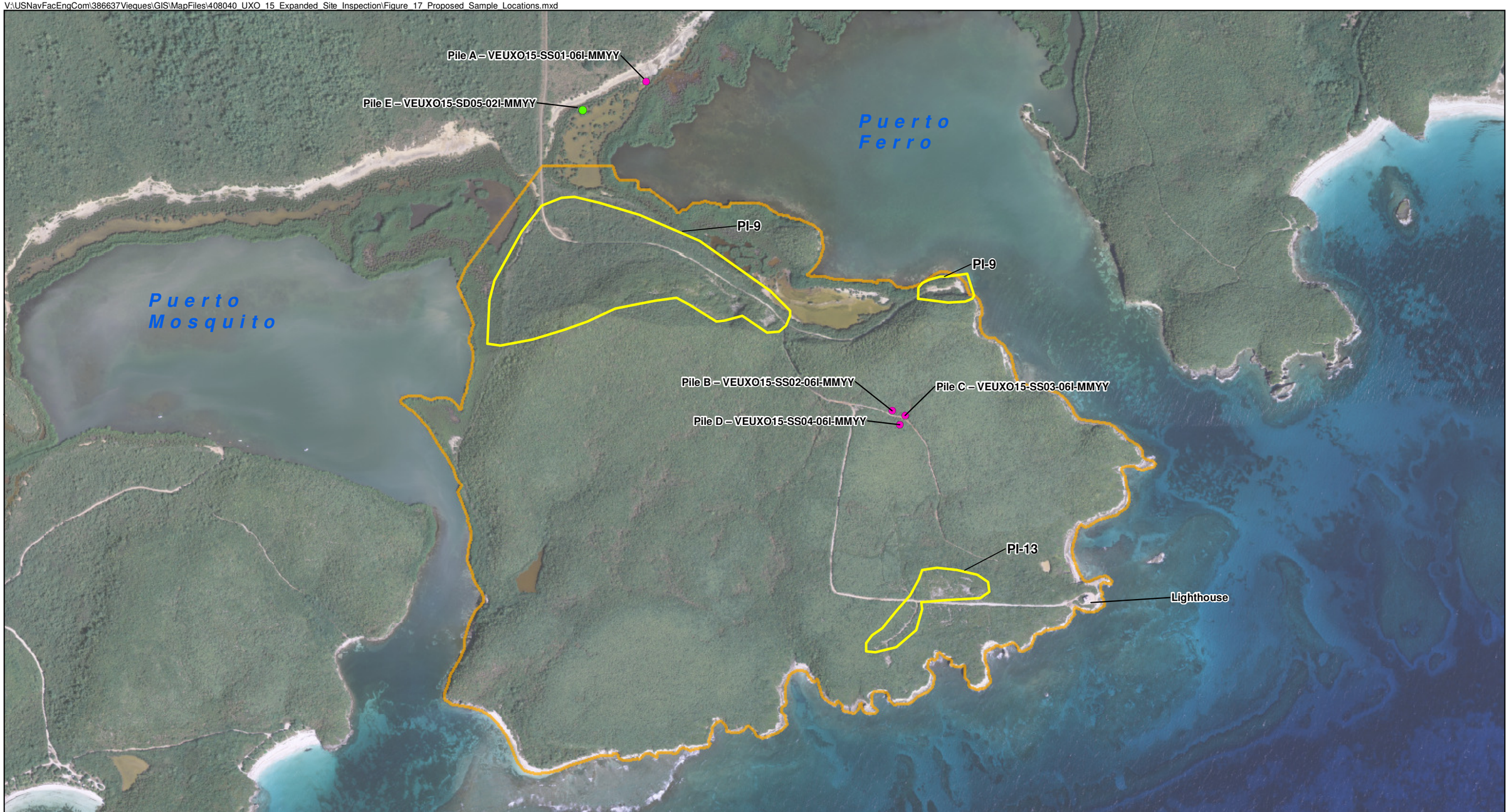
0 425 850 1,700 Feet

Figure 16
Topographic Map (USGS)
UXO 15 - Expanded Site Inspection Sampling and Analysis Plan
Vieques, Puerto Rico

2007 Aerial Photo

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\408040_UXO_15_Expanded_Site_Inspection\Figure_17_Proposed_Sample_Locations.mxd



Legend
- Debris Pile and Proposed Soil Sample Location
- Small Arms Pile and Proposed Sediment Sample Location
- PI SIte
- UXO Site

N
W E
S

0 425 850 1,700
Feet

Figure 17
Proposed Sample Locations
UXO 15 - Expanded Site Inspection Sampling and Analysis Plan
Vieques, Puerto Rico

2007 Aerial Photo

CH2MHILL

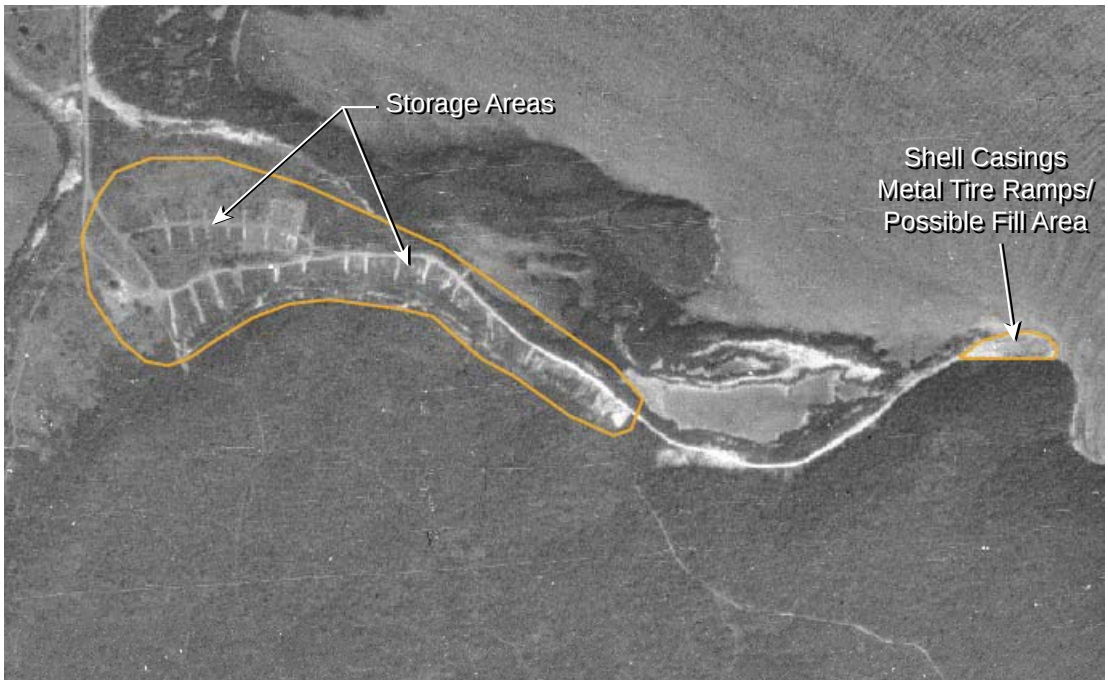


Figure 18 1959 Aerial Photo of PI-9. Orange line denotes area of activity since 1936 identified by ERI, Inc.

Figure 19 1962 Aerial Photo of PI-9. Purple line denotes area of activity since 1959 identified by ERI, Inc.

Figure 20 1964 Aerial Photo of PI-9. Green line denotes area of activity since 1962 identified by ERI, Inc.

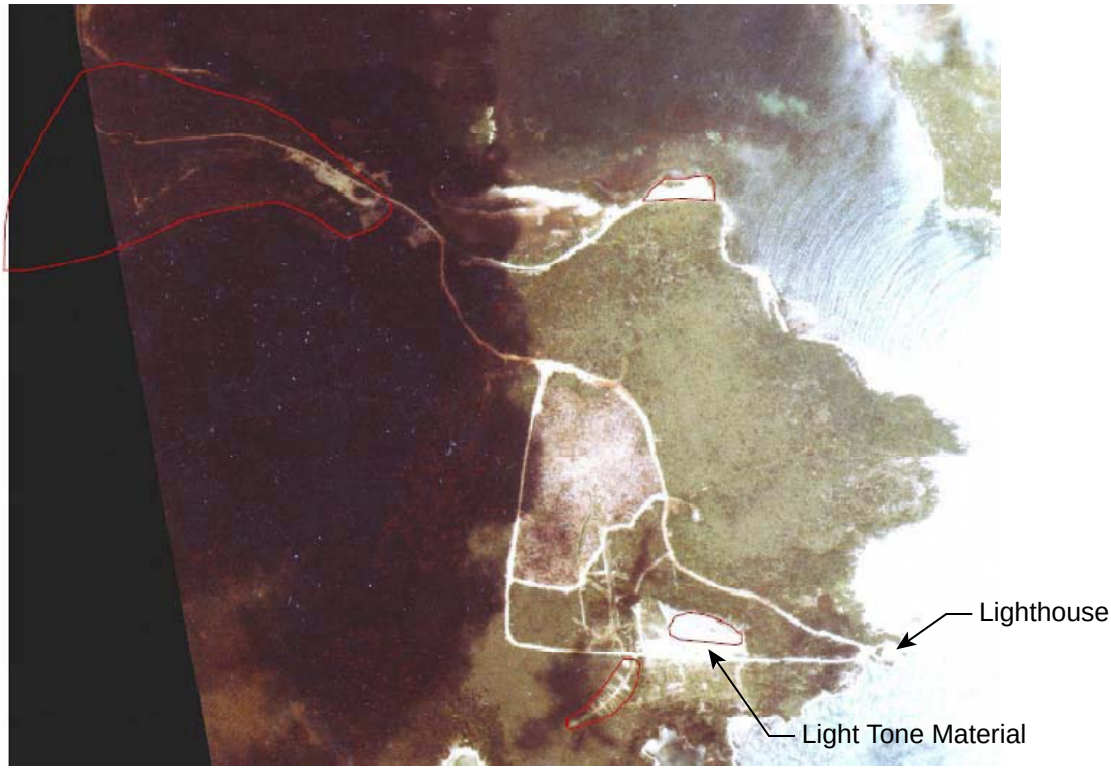


Figure 21 1970 Aerial Photo of UXO-15

Attachment A
Field SOPs

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STANDARD OPERATING PROCEDURE A-2

Soil Sampling

I. Purpose and Scope

The purpose of this procedure is to provide standardized procedures for obtaining samples of surface and subsurface soils. Any project required deviations from Standard Operating Procedures (SOPs), will be provided in site specific Sampling and Analysis Plans (SAPs).

II. Equipment and Materials

- Personal Protection Equipment
- Stainless-steel hand auger, split spoon, or appropriate hand tool
- Thin-walled sampling tubes (such as a shelby tube)
- Direct-push rig, drilling rig, soil-coring rig, or hand auger equipment
- Stainless-steel pan or bowl
- Stainless-steel spoons or dedicated wooden spoons
- Sample bottles and equipment
- photo-ionization detector (PID) or flame-ionization detector (FID)

III. Procedures and Guidelines

All personnel shall be wearing personal protective equipment (PPE) per health and safety plan (HASP). Decontaminate all equipment per SOP "*Decontamination of Drilling Rigs and Equipment*" and "*Decontamination of Personnel and Equipment.*" Locate and record the sample point in the logbook. If appropriate, record sample location using global positioning system (GPS) or land survey.

A. Surface and Shallow Subsurface Sampling with Hand Auger

Remove soil to a point just above the interval to be sampled. Collect soil at the desired sampling depth. Immediately take soil for volatile organic compound (VOC) analysis directly from the end of the hand auger with an Encore sampler. Place soil for analyses other than VOCs into a stainless-steel bowl, take a PID or FID reading of the soil collected, and log the readings accordingly into the boring (or other) log. Mix the soil in the bowl according to "*Homogenization of Soil and Sediment Samples*" SOP. If this interval is to be collected for analysis, use a stainless-steel spoon or dedicated wooden spoon to transfer the sample from the bowl to the sample container(s). Try not to touch soil to be collected with bare or gloved hands. Soil samples in sample containers should be free of pebbles, roots, and other non-soil debris. Preferably, soil jars should be filled full, but if difficulties are

encountered in getting sample volume, see SAP for minimum sample volume required by lab, or have the Environmental Information Specialist (EIS) call lab for minimum volume lab will need for that/those analyses. For VOC samples in jars, fill completely to avoid headspace. For VOC samples in Encore® samplers see SOP *"Soil Sampling for VOCs using the Encore ® Sampler"*. For VOC samples in Terra core® samplers see SOP *"Soil Sampling for VOCs using the Terra core ® Sampler"*.

B. Split-Spoon or Direct Push Sampling

Advance a boring to just above the sample depth using a drilling rig, slide hammer, or direct push technology (DPT) rig. Lower the sampler into the hole and advance it to a depth equal to the total length of the desired interval. If using a drilling rig, or slide hammer, advance the split spoon sampler using a weighted or pneumatic hammer. Record the weight, type, blow count (number of blows required to advance 6 inches), and penetrated length into the boring log. Record only the penetrated length if using DPT.

The driller will then open the sampler or extrude the lexan (or similar) sample tube and cut open the tube, leaving the cut piece of tube on the sample to minimize the possibility of soil and vapors to escape. Record the total length of sample retrieved. Using a PID or FID, take readings along several points of the sampler and record them. Also, record any visual observations of suspected contamination. If this interval is to be collected, samples for VOC analysis are to be collected immediately from the core or split spoon at the target location (based on visual observations and PID/FID readings). Samples for analyses other than VOCs should be homogenized according to *"Homogenization of Soil and Sediment Samples"* SOP. Additional sample volume may be obtained by collecting a second sample below the first sample and compositing the sample for non-volatile parameters only (if still within the desired sample depth interval). A co-located hole within approximately 2 feet from the first hole may also be used to collect additional sample volume.

C. Thin-Walled Tube Sampling

Undisturbed samples may be collected for analysis for physical parameters such as vertical hydraulic conductivity. These samples will be collected using thin-walled sampling tubes (sometimes called Shelby tubes) according to ASTM D 1587 (attached). Tubes will be 24 to 36 inches long and 3 to 4 inches in diameter, depending upon the quantity of sample required. Undisturbed samples will be obtained by smoothly pressing the sampling tube through the interval to be sampled using the weight of the drilling rig. Jerking the sample should be avoided. Once the sample is brought to the surface, the ends will be sealed with bees wax (or comparable) and then sealed with end caps and tape. The sample designation, date and time of sampling, and the up direction will be noted on the sampling tube. The tube shall be kept upright as much as possible and will be protected from freezing.

D. Sampling Descriptions

Following sample retrieval, the soils should be visually described in the boring log using ASTM D 2488, (attached) including approximated depths, PID readings, and any other relevant observations. Use the standard CH2M HILL soil description format found on soil boring log headers:: soil name, USCS group symbol, Munsell number and color, moisture content, relative density or consistency, soil structure, mineralogy (note approximate percentages of sand, silt and clay). Use a measuring tape or folding ruler calibrated in feet

and 10ths for logging soils. Note the depths that drilling penetration is easier/faster. Note at what depth drillers switched from augering to air hammer, as applicable. Make sure to note at what depth soil becomes saturated (and if it appears to return to an unsaturated state, indicating pearched water).

IV. Key Checks and Preventative Maintenance

- Decontamination of all non-disposable equipment between sampling locations.
- PID/FID calibration and checks.

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Designation: D 1587 – 08

Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes[1]

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively intact soil samples suitable for laboratory tests of engineering properties, such as strength, compressibility, permeability, and density. Thin-walled tubes used in piston, plug, or rotary-type samplers should comply with Section 6.3 of this practice which describes the thin-walled tubes.

NOTE 1—This practice does not apply to liners used within the samplers.

1.2 This Practice is limited to soils that can be penetrated by the thin-walled tube. This sampling method is not recommended for sampling soils containing gravel or larger size soil particles cemented or very hard soils. Other soil samplers may be used for sampling these soil types. Such samplers include driven split barrel samplers and soil coring devices (D 1586, D 3550, and D 6151). For information on appropriate use of other soil samplers refer to D 6169.

1.3 This practice is often used in conjunction with fluid rotary drilling (D 1452, D 5783) or hollow-stem augers (D 6151). Subsurface geotechnical explorations should be reported in accordance with practice (D 5434). This practice discusses some aspects of sample preservation after the sampling event. For information on preservation and transportation process of soil samples, consult Practice D 4220. This practice does not address environmental sampling; consult D 6169 and D 6232 for information on sampling for environmental investigations.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4.1 The tubing tolerances presented in Table 1 are from sources available in North America. Use of metric equivalent is acceptable as long as thickness and proportions are similar to those required in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1452 Practice for Soil Investigation and Sampling by Auger Borings

D 1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D 3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

D 3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D 4220 Practices for Preserving and Transporting Soil Samples

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

Current edition approved Oct. 1, 2008. Published October 2008. Originally approved in 1958. Last previous edition approved in 2007 as D 1587 – 00 (2007)$^{\varepsilon 1}$.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Dimensional Tolerances for Thin-Walled Tubes

	Nominal Tube Diameters from Table 2[A] Tolerances					
Size Outside Diameter	2 in.	50.8 mm	3 in.	76.2 mm	5 in.	127 mm
Outside diameter, D_o	+0.007 -0.000	+0.179 -0.000	+0.010 -0.000	+0.254 -0.000	+0.015 -0.000	0.381 -0.000
Inside diameter, D_i	+0.000 -0.007	+0.000 -0.179	+0.000 -0.010	+0.000 -0.254	+0.000 -0.015	+0.000 -0.381
Wall thickness	±0.007	±0.179	±0.010	±0.254	±0.015	±0.381
Ovality	0.015	0.381	0.020	0.508	0.030	0.762
Straightness	0.030/ft	2.50/m	0.030/ft	2.50/m	0.030/ft	2.50/m

[A] Intermediate or larger diameters should be proportional. Specify only two of the first three tolerances; that is, D_o and D_i, or D_o and Wall thickness, or D_i and Wall thickness.

D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock

D 5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices

D 6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

D 6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations

D 6232 Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms in this standard, refer to Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *inside clearance ratio, %, n*—the ratio of the difference in the inside diameter of the tube, D_i, minus the inside diameter of the cutting edge, D_e, to the inside diameter of the tube, D_i expressed as a percentage (see Fig. 1).

3.2.2 *ovality, n*—the cross section of the tube that deviates from a perfect circle.

4. Summary of Practice

4.1 A relatively intact sample is obtained by pressing a thin-walled metal tube into the in-situ soil at the bottom of a boring, removing the soil-filled tube, and applying seals to the soil surfaces to prevent soil movement and moisture gain or loss.

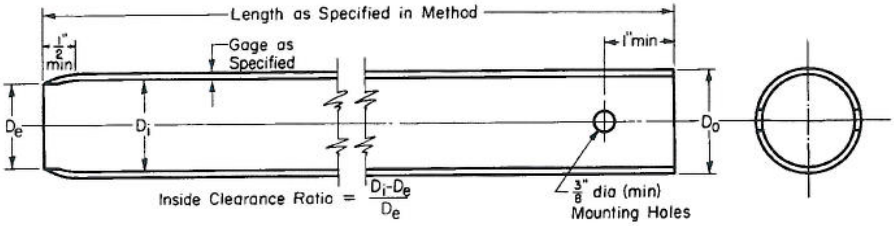
5. Significance and Use

5.1 This practice, or Practice D 3550 with thin wall shoe, is used when it is necessary to obtain a relatively intact specimen suitable for laboratory tests of engineering properties or other tests that might be influenced by soil disturbance.

NOTE 2—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective sampling. Users of this practice. are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Drilling Equipment*—When sampling in a boring, any drilling equipment may be used that provides a reasonably clean hole; that minimizes disturbance of the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside



NOTE 1—Minimum of two mounting holes on opposite sides for D_o smaller than 4 in. (101.6 mm).

NOTE 2—Minimum of four mounting holes equally spaced for D_o 4 in. (101.6 mm) and larger.

NOTE 3—Tube held with hardened screws or other suitable means.

NOTE 4—2-in (50.8 mm) outside-diameter tubes are specified with an 18-gauge wall thickness to comply with area ratio criteria accepted for "intact samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gauge tubes are generally readily available.

Metric Equivalent Conversions

in.	mm
3/8	9.53
1/2	12.7
1	25.4
2	50.8
3	76.2
4	101.6
5	127

FIG. 1 Thin-Walled Tube for Sampling

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TABLE 2 Suitable Thin-Walled Steel Sample Tubes[A]

Outside diameter (D_o):			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Inside clearance ratio, %	<1	<1	<1

[A] The three diameters recommended in Table 2 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

6.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

6.3 *Thin-Walled Tubes*, should be manufactured to the dimensions as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. (50 to 130 mm) and be made of metal having adequate strength for the type of soil to be sampled. Tubes shall be clean and free of all surface irregularities including projecting weld seams. Other diameters may be used but the tube dimensions should be proportional to the tube designs presented here.

6.3.1 *Length of Tubes*—See Table 2 and 7.4.1.

6.3.2 *Tolerances*, shall be within the limits shown in Table 1.

6.3.3 *Inside Clearance Ratio*, should be not greater than 1 % unless specified otherwise for the type of soil to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled, except for sensitive soils or where local experience indicates otherwise. See 3.2.1 and Fig. 1 for definition of inside clearance ratio.

6.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating, unless the soil is to be extruded less than 3 days. The type of coating to be used may vary depending upon the material to be sampled. Plating of the tubes or alternate base metals may be specified. Galvanized tubes are often used when long term storage is required. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, zinc oxide, and others.

NOTE 3—Most coating materials are not resistant to scratching by soils that contain sands. Consideration should be given for prompt testing of the sample because chemical reactions between the metal and the soil sample con occur with time.

6.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a venting area and suitable check valve with the venting area to the outside equal to or greater than the area through the check valve. In some special cases, a check valve may not be required but venting is required to avoid sample compression. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

7. Procedure

7.1 Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the drilling and sampling operation.

7.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted.

NOTE 4—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

7.3 Lower the sampling apparatus so that the sample tube's bottom rests on the bottom of the hole and record depth to the bottom of the sample tube to the nearest 0.1-ft (0.03 m).

7.3.1 Keep the sampling apparatus plumb during lowering, thereby preventing the cutting edge of the tube from scraping the wall of the borehole.

7.4 Advance the sampler without rotation by a continuous relatively rapid downward motion and record length of advancement to the nearest 1 in. (25 mm).

7.4.1 Determine the length of advance by the resistance and condition of the soil formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays. In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. (76 mm) for sludge and end cuttings.

NOTE 5—The mass of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 2.

7.5 When the soil formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

7.6 Withdraw the sampler from the soil formation as carefully as possible in order to minimize disturbance of the sample. The tube can be slowly rotated to shear the material at the end of the tube, and to relieve water or suction pressures (or both) and improve recovery. Where the soil formation is soft, a delay before withdraw of the sampler (typically 5 to 30 minutes) may improve sample recovery.

8. Sample Measurement, Sealing and Labeling

8.1 Upon removal of the tube, remove the drill cuttings in the upper end of the tube and measure the length of the soil sample recovered to the nearest 0.25 in. (6 mm) in the tube. Seal the upper end of the tube. Remove at least 1 in. (25 mm)

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of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube.

8.1.1 Tubes sealed over the ends, as opposed to those sealed with expanding packers, should be provided with spacers or appropriate packing materials, or both prior to sealing the tube ends to provide proper confinement. Packing materials must be nonabsorbent and must maintain their properties to provide the same degree of sample support with time.

8.1.2 Depending on the requirements of the investigation, field extrusion and packaging of extruded soil samples can be performed. This allows for physical examination and classification of the sample. Samples are extruded in special hydraulic jacks equipped with properly sized platens to extrude the core in a continuous smooth speed. In some cases, further extrusion may cause sample disturbance reducing suitability for testing of engineering properties. In other cases, if damage is not significant, cores can be extruded and preserved for testing (Practice D 4220). Bent or damaged tubes should be cut off before extruding.

8.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample (see Section 9). Assure that the markings or labels are adequate to survive transportation and storage.

NOTE 6—Top end of the tube should be labeled "top."

9. Field Log

9.1 Record the information that may be required for preparing field logs in general accordance to Guide D 5434. This guide is used for logging explorations by drilling and sampling. Some examples of the information required include;

9.1.1 Name and location of the project,

9.1.2 Boring number,

9.1.3 Log of the soil conditions,

9.1.4 Surface elevation or reference to a datum to the nearest foot (0.5 m) or better,

9.1.5 Location of the boring,

9.1.6 Method of making the borehole,

9.1.7 Name of the drilling foreman and company, and

9.1.8 Name of the drilling inspector(s).

9.1.9 Date and time of boring-start and finish,

9.1.10 Depth to groundwater level: date and time measured,

9.2 Recording the appropriate sampling information is required as follows:

9.2.1 Depth to top of sample to the nearest 0.1 ft. (.03 m) and number of sample,

9.2.2 Description of thin-walled tube sampler: size, type of metal, type of coating,

9.2.3 Method of sampler insertion: push or drive,

9.2.4 Method of drilling, size of hole, casing, and drilling fluid used,

9.2.5 Soil description in accordance with Practice D 2488,

9.2.6 Length of sampler advance (push), and

9.2.7 Recovery: length of sample obtained.

10. Keywords

10.1 geologic investigations; intact; sampling; soil exploration; soil investigations; subsurface investigations

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D 1587 – 00 (2007)$^{\varepsilon 1}$) that may impact the use of this standard. (Approved October 1, 2008.)

(*1*) Replaced "undisturbed" with "intact" in Sections 1.1, 4.1, 5.1, 10, and Note 4 of Fig. 1.

(*2*) Editorial changes made in Sections 1.4, 7.3, 7.4.1, 7.6, 8.1, and 8.1.2.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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Designation: D 2488 – 00

Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)[1]

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.6 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)[2]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and rock as Used in Engineering Design and Construction[3]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[2]

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:
Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and
Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75-µm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Feb. 10, 2000. Published May 2000. Originally published as D 2488 – 66 T. Last previous edition D 2488 – 93ϵ1.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

***A Summary of Changes section appears at the end of this standard.**

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limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Fig. 1a and Fig. 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols.*

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means for evaluating some of those factors.

6. Apparatus

6.1 *Required Apparatus*:

6.1.1 *Pocket Knife or Small Spatula*.

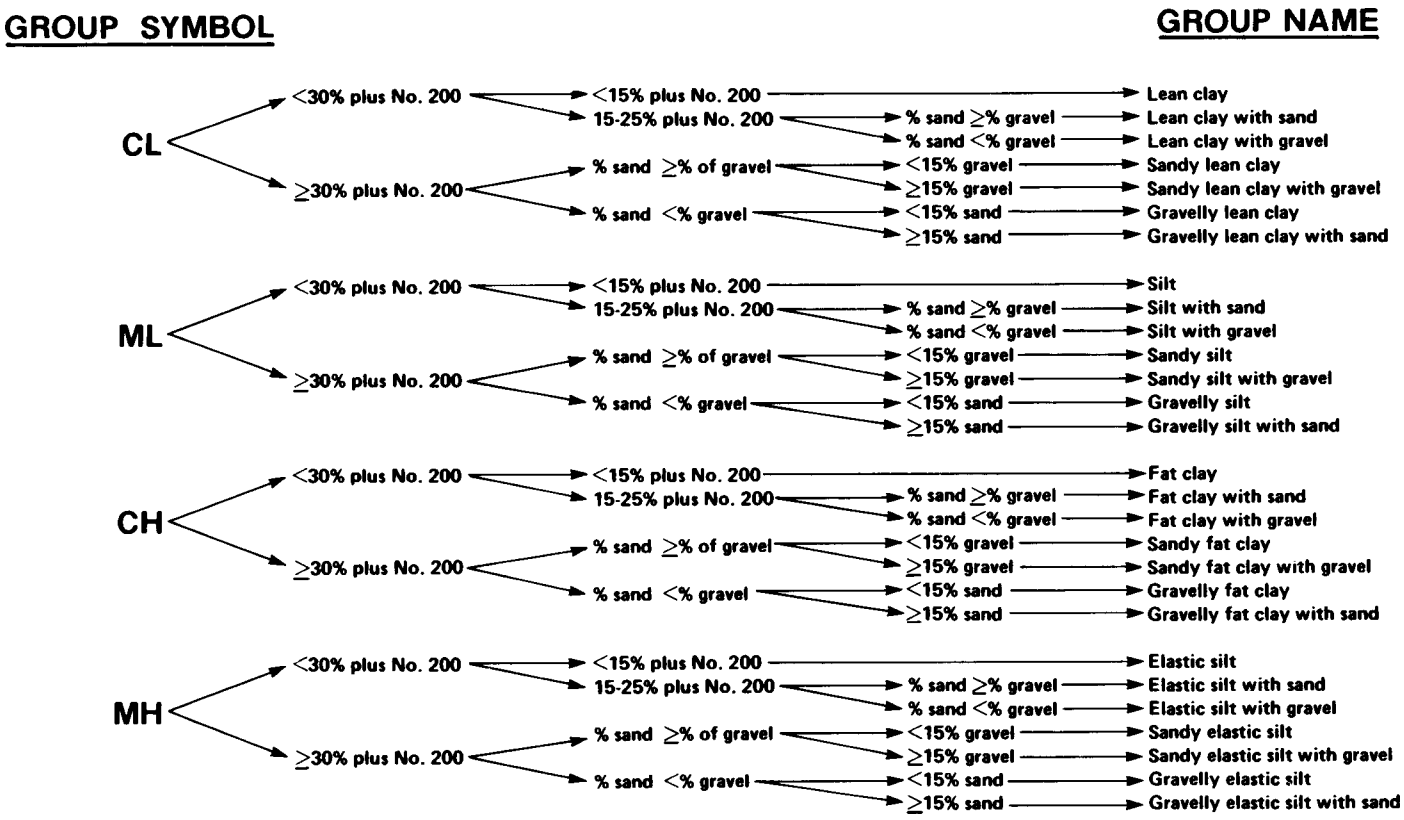
6.2 *Useful Auxiliary Apparatus*:

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens*.

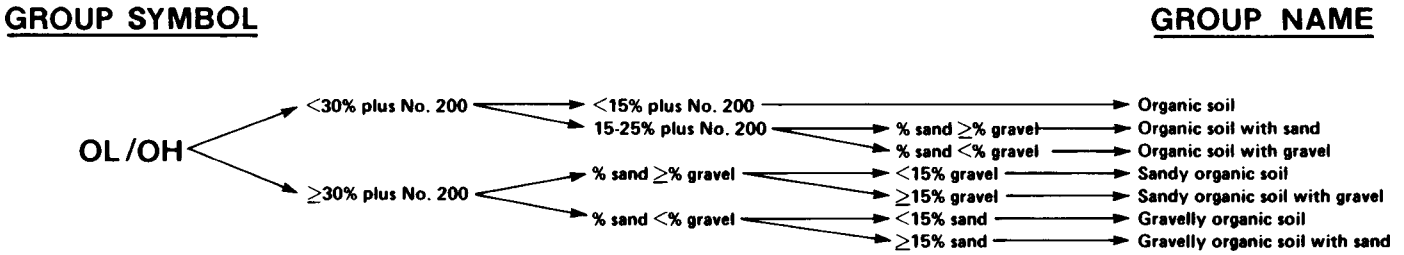
7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1 b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)

supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 *N*) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 **Caution**—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

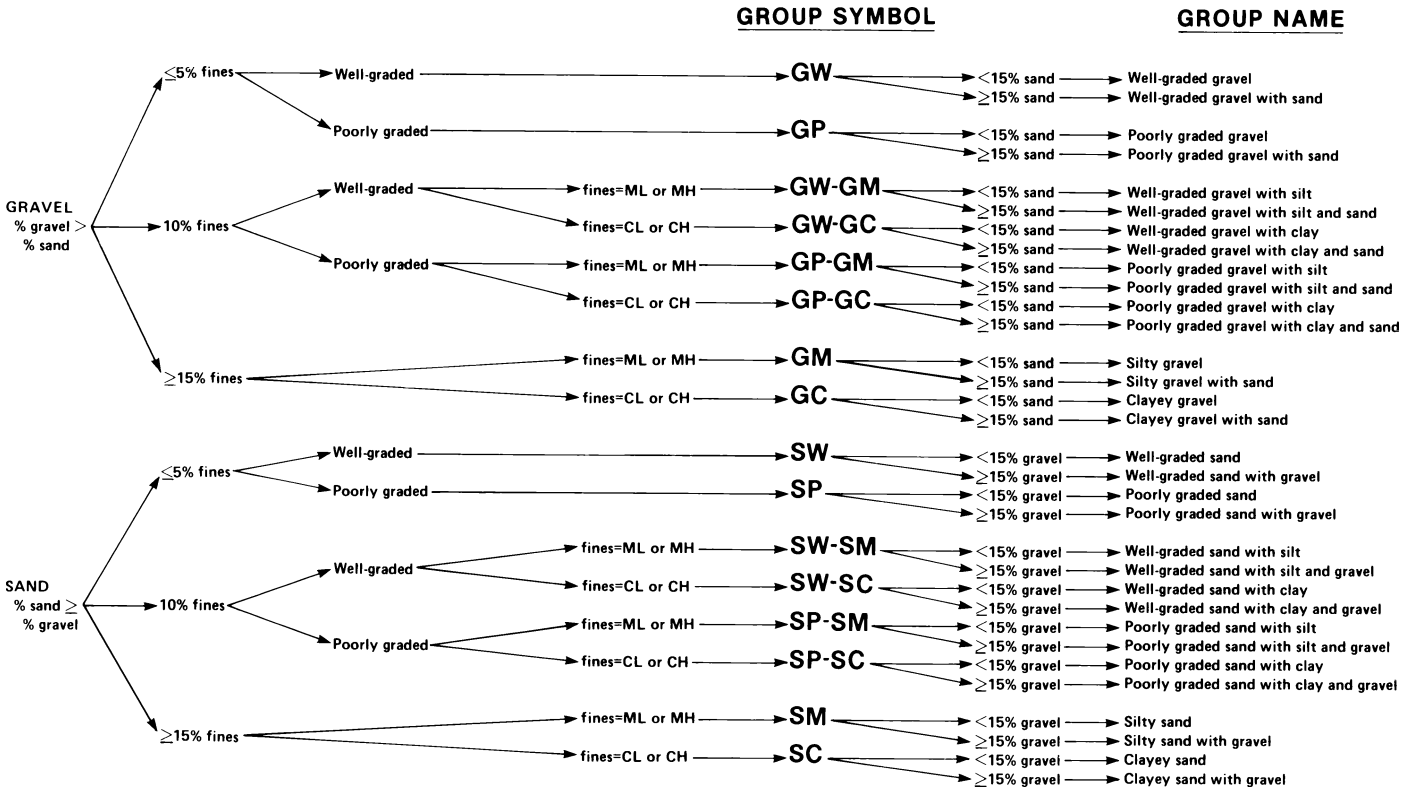
NOTE 6—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Test Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 7—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (⅜ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

NOTE 8—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

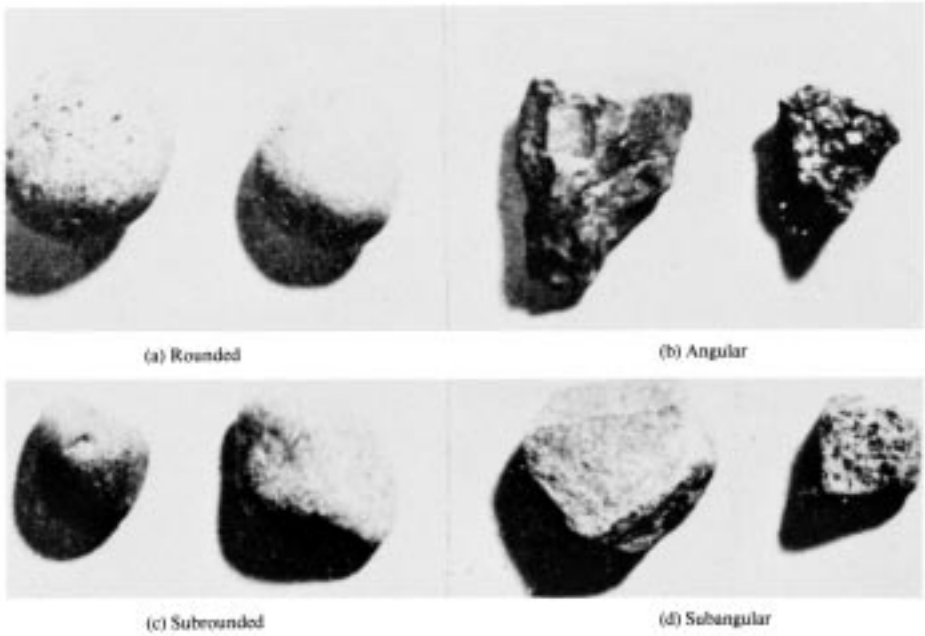


FIG. 3 Typical Angularity of Bulky Grains

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.	
Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

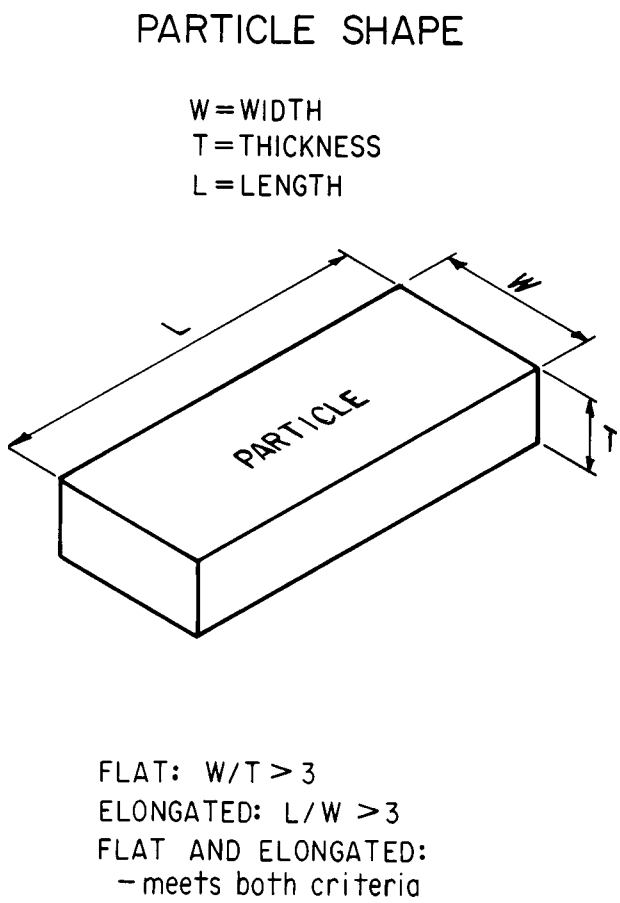


FIG. 4 Criteria for Particle Shape

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Dilatancy

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

TABLE 6 Criteria for Describing Toughness

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Dilatancy

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 9—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 10—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength*:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 11—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low,

medium, high, or very high in accorance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy*:

14.3.1 From the specimen, select enough material to mold into a ball about ½ in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness*:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about ⅛ in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about ⅛ in. The thread will crumble at a diameter of ⅛ in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

TABLE 8 Criteria for Describing Toughness

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7 *Identification of Inorganic Fine-Grained Soils*:

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 12—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

14.8 *Identification of Organic Fine-Grained Soils*:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 13—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils

(Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 14—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 15—Other examples of soil descriptions and identification are given in Appendix X1 and Appendix X2.

NOTE 16—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %
Few—5 to 10 %
Little—15 to 25 %
Some—30 to 45 %
Mostly—50 to 100 %

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel—fine, coarse
   Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

For intact samples:

18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as “Sandy Lean Clay (CL)”; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; “Poorly Graded Sand with Silt (SP-SM)”; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; “Poorly Graded Gravel with Sand (GP).”

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; “Poorly Graded Gravel (GP)”; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard,

angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:	Suffix:

s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (1993$^{\epsilon 1}$) that may impact the use of this standard.

(1) Added Practice D 3740 to Section 2.

(2) Added Note 5 under 5.7 and renumbered subsequent notes.

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STANDARD OPERATING PROCEDURE A-3

Homogenization of Soil and Sediment Samples

I. Purpose and Scope

This document provides standardized procedures for the homogenization of soil and sediment samples. Any project required deviations from Standard Operating Procedures (SOPs), will be provided in site specific Sampling and Analysis Plans (SAPs).

II. Equipment and Materials

- Stainless steel spoons or spatulas, disposable wooden sampling tools
- Stainless steel pans or bowls

III. Procedures and Guidelines

Soil and sediment samples to be analyzed for non-volatile organic compound (VOC) chemical analyses will be homogenized in the field. Samples for VOCs will not be collected from homogenized soil or sediment. A stainless steel spatula, stainless spoon, or disposable wooden device will be used to remove the soil from the split spoon or other sampling device into a stainless-steel pan or bowl. Do not touch soil to be collected with bare or gloved hands.

Prior to homogenization, any rocks, twigs, leaves, or other debris should be removed from the sample to the extent practical. The soil should be placed in a decontaminated stainless steel bowl (or similar) and thoroughly mixed using a stainless steel spoon (or similar).

All stainless steel spoons, spatulas, and bowls must be decontaminated following procedures specified in SOP *Decontamination of Personnel and Equipment* prior to homogenizing the sample.

IV. Key Checks and Items

- Take VOC samples from undisturbed soil and sediment; do not collect VOC samples from homogenized soil or sediment.
- Decontaminate all non-disposable equipment between sampling locations.
- Make sure homogenization equipment (bowls and spoons) are intact and not rusting or flaking.

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STANDARD OPERATING PROCEDURE E-1

Decontamination of Personnel and Equipment

I. Purpose and Scope

This standard operating procedure (SOP) provides standardized procedures for the decontamination of personnel, sampling equipment, and monitoring equipment used in potentially contaminated environments. Any project required deviations from SOPs, will be provided in site specific sampling and analysis plans (SAPs).

II. Equipment and Materials

1. Potable water from a municipal water supplier.
2. ASTM Type II reagent water with analysis certification.
3. Soap solution, such as 2.5% (W/W) Liquinox, or Alconox.
4. 10% solvent such as methanol, isopropyl, hexane or other approved solvent (DO NOT USE ACETONE). Pesticide-grade solvents will only be used if directed by project-specific SAPs.
5. Large plastic pails or tubs, scrub brushes, squirt bottles for soap and solvent solutions, plastic bags and sheets.
6. Department of transportation approved 55-gallon drum for disposal of waste (if required)Personal protective equipment (PPE).

III. Procedures and Guidelines

A. Personnel Decontamination

This is a guide, and may be modified if the contamination is less or more than what is required here.

- Only if there is gross contamination present that cannot be removed using the procedures below should the PPE be disposed of with investigation derived waste (IDW).
- Wash boots in soap solution and rinse with water. If disposable latex booties are worn over boots in the work area, rinse with soap solution, remove, and discard with normal trash.
- Wash outer gloves in soap solution, rinse, remove, and discard with normal trash.
- Remove disposable coveralls ("Tyveks"), wash any obvious dirt or contamination off with soap solution, rinse, and discard with normal trash.

- Remove respirator (if worn).
- Remove inner gloves and discard with normal trash.
- Sanitize respirator if worn in accordance with manufacturer's instructions.
- At the end of the work day, shower entire body, including hair, either at the work site or at home.

B. Sampling Pump Decontamination

- Don disposable gloves.
- Spread plastic on the ground to keep hoses from touching the ground.
- Turn off pump after sampling. Remove pump from well and place pump in decontamination container.
- Pre-rinse the pump in potable water to remove bulk soil or contamination.
- Disassemble pump, as practical, and scrub pump with soap solution. If disassembly of pump not practical, run solution through pump for 1 minute.
- Scrub in tap water, then reassemble and run pump in tap water for one minute.
- Disassemble and spray pump with 70-100% solvent solution. (DO NOT USE ACETONE). If disassembly of pump not practical, run 10 percent solution through pump for 1 minute.
- Allow to air dry.
- Spray with ASTM type II reagent water with analysis certification.
- Reassemble and wrap pump in aluminum foil or clean plastic sheeting and place into decontamination tube.
- Collect all rinsate and dispose of according to the Master Waste Management Plan.
- Decontamination materials (e.g., plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment can be decontaminated (using the above procedure) and disposed of with normal trash or can be disposed of according to the Master Waste Management Plan.

C. Other Sampling Equipment Decontamination

- Don latex-free gloves.
- Pre-rinse and scrub equipment with potable water.
- Wash all equipment surfaces that contacted the potentially contaminated soil/water with soap solution.
- Rinse with potable water.
- Rinse with distilled water and 10% solvent solution.

- Air dry.
- Rinse with ASTM type II reagent water with analysis certification.
- Completely air dry and wrap exposed areas with aluminum foil (shiny side out) for transport and handling.
- Collect all rinsate and dispose of according to the Master Waste Management Plan.
- Decontamination materials (e.g., plastic sheeting, tubing, etc.) that have come in contact with used decontamination fluids or sampling equipment can decontaminated (using the above procedure) and disposed of with normal trash or can be disposed of according to the Master Waste Management Plan.

D. Sample Container Exterior Decontamination

- The outsides of sample bottles or containers filled in the field may need to be decontaminated before being packed for shipment or handled by personnel without hand protection.
- Wipe container with a paper towel dampened with soap solution. Repeat the above steps using potable water.
- Dispose of all used paper towels according to the Master Waste Management Plan.

E. Water Level Meter

Water level meters will be decontaminated before being used in the first well, and after measuring each well as follows:

1. Wipe tape, first with a towel dampened with 10 percent solvent solution, then with a towel dampened with DI water.
2. Spray off probe, first with 10 percent solvent solution, then with ASTM type II reagent water with analysis certification.

IV. Key Checks and Items

- Clean with solutions of soap, solvent, and ASTM type II reagent water with analysis certification.
- Do not use acetone for decontamination.
- Minimize generation of IDW to the maximum extent possible by decontaminating to the extent practical and disposing with normal trash.

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STANDARD OPERATING PROCEDURE G-2

Sediment Sampling

I. Purpose

These standardized procedures describe the collection and handling of sediment samples during field operations.

II. Scope

Sediments occur in freshwater and marine environments such as streams/rivers, ponds/lakes, canals, ditches, wetlands, lagoons, and estuaries. The sediment sampling procedures generally describe the equipment and techniques needed to collect representative sediment samples. Always collect surface water quality samples prior to collecting sediment samples if sampling locations are located with or near each other.

The sampling team will document the site conditions (e.g., surrounding land use, surface water characteristics, obvious nearby sources of contamination) and sediment characteristics (e.g., color, texture, odor, sediment depth sampled) through a brief description in the logbook, sediment log sheet, and/or representative site photos. It is also important to document that the media being sampled is in fact sediment (and not soil), meaning that overlying water was present at the time of sampling, or that there is obvious evidence of frequent and recent inundation (e.g., sampling exposed sediment at low tide). Any project required deviations from the standard operating procedures (SOPs) will be provided in the site specific sampling and analysis plan (SAP).

III. Equipment and Materials

- Sample collection device (hand corer, scoop, dredge, grab sampler, or other suitable device).
- Rope to lower sediment grab or dredge.
- Measuring tape to measure water depth.
- Sediment log sheets.
- Camera (to document sample characteristics and site conditions).
- Hip waders.
- Materials for classifying soils, particularly the percentage of fines.
- Sample jars, including jars for grain size, total organic carbon, and pH, as appropriate.
- Boat or canoe with U.S. Coast Guard-approved safety equipment.

IV. Procedures and Guidelines

Sediment samples can be collected using one of three different types of equipment: (1) scoops, (2) corers and (3) dredges/grab samplers. Soil sampling equipment is generally not applicable to sediments because of the low cohesion of the medium, but may be used if appropriate. When selecting the appropriate sampling equipment, consider sampling location (edge or middle of lagoon), depth of water and sediment, sediment grain size (fineness), water velocity, and analytes of interest.

Direct collection with the appropriate sample container may be appropriate in very low water or where sediment is exposed. Use dredges for hard or rocky substrates (can also be used for fine sediment). They are heavy enough to use in high velocity streams. Use coring devices in quiescent waters, unless water depth precludes effective sample collection. Always note the depth of sediment actually collected; environmental and mechanical factors may prevent collection to targeted depth (e.g., 0-6 inches).

A. Scoops or Similar Equipment

- Scooping is generally most useful in shallow waters, and where water flow is minimal so as not to disturbed the scooped sample as it is brought up through the water column. Collect samples by facing the direction of minimal flow and approach the location from the downstream direction. Take precautions not to disturb the bottom prior to scooping. Scoop and transfer the sample to the appropriate sample container(s) or to a decontaminated bowl if homogenization is required.

B. Corers

Coring devices can be easily fabricated from many materials. Some corers are simple "push tubes," whereas other more sophisticated models may be finned, gravity driven devices. A core may be useful for preserving the historical layering of sediments.

The corer is an acceptable choice for sampling fine sediments. Corer diameter, grain size, and sample consistency will determine if the sample will remain in the corer upon withdrawal. Sample washout can be a problem, and ways to reduce or prevent it are as follows:

- Fit the leading edge of the corer with a nosepiece or core catcher that physically keeps the sample from slipping back out of the corer. The core catcher material must also be compatible with the analytes of interest.
- A second option is fit the top or back end with a check valve which creates negative pressure as it is being pulled from the substrate, and prevents surface water from washing out the top portion of the sample.
- Rotate the corer, if needed, as it is pushed into the sediment but do not rock the coring device back and forth. Rotation improves penetration and prevents compaction of the sample.
- Upon withdrawal from the water surface, place a cap on the bottom to prevent the sample from sliding out.

- Corers can also be fitted with liners if a complete core is desired.
- As the core is extruded, carefully remove the sample with a decontaminated, non-reactive utensil and transfer into the appropriate sample container(s) or a bowl if homogenization is required or if a specific depth fraction is required to be sampled.

C. Dredges or Grab Samplers

The three main types of devices used in freshwater are the Peterson, Ponar, and Ekman. The Peterson and Ponar dredges are suitable for hard or rocky substrates, deep water bodies, and streams with fast currents. The Peterson and Ponar are virtually the same, except that the Ponar has been adapted with a top screen and side plates to prevent sample loss upon ascent. Use the following method to collect a sediment sample:

- Open the jaws and place the cross bar into the proper notch.
- Lower the dredge to the bottom, making sure it settles flat.
- When tension is removed from the line, the cross bar will drop, enabling the dredge to close as the line is pulled upward during retrieval.
- Pull the sampler to the surface. Check to make sure the jaws are fully closed and that no sample was lost while lifting the dredge.
- Carefully open the jaws, remove the sample with a decontaminated, non-reactive utensil and transfer the sample into the appropriate sample container(s) or bowl for homogenization.

The Ekman is designed for sampling soft substrates (e.g., sand, silt, or mud) in areas with little current and is used as follows:

- Open the spring-loaded jaws and attach the chains to the pegs at the top of the sampler.
- Lower the dredge to the bottom, making sure it settles flat.
- Holding the line taut, send down the messenger to close the jaws of the dredge.
- Pull the sampler to the surface. Check to make sure the jaws are fully closed and that no sample was lost while lifting the dredge.
- Carefully open the jaws, remove the sample with a clean, non-reactive utensil and transfer the sample into the appropriate sample container(s) or bowl for homogenization.

D. General Sampling Procedures

1. Field personnel will start downstream and work upstream to prevent disturbance of or influence on unsampled areas. In surface water bodies that are tidally influenced, sampling should be performed at low tide and under low flow conditions to minimize the dilution of possible contaminants; however, sampling at other tide stages may be warranted to provide data representative of other, actual conditions. Sediment sampling activities should not occur immediately after periods of heavy rainfall.

2. As needed, make a sketch of the sample area that shows important nearby river features and permanent structures that can be used to locate the sample points on a map. Use a GPS to gather station coordinates, if needed. Also characterize depth and width of waterway, rate of flow, type, consistency, and odor of sediment, and point and depth of sample removal (along shore, mid-channel, etc.).
3. Transfer sample into appropriate sample jars with a stainless steel utensil. Be especially careful to avoid the loss of the very fine clay/silt particles when collecting the sample. Minimize the amount of overlying water that is collected with the sample matrix. Decant the excess water off of the sample slowly and carefully to maximize retention of the very fine particles. The sampler's fingers should never touch the sediment since skin or gloves may introduce organic interference into the sample. Classify the soil type of the sample using the Unified Soil Classification System, noting particularly the percentage of silt and clay.
4. Samples for volatile organics (and, if applicable, acid volatile sulfides/simultaneously extracted metals [AVS/SEM]) should immediately be placed in jars prior to homogenization of sediment. Rocks and other debris should be removed with utensils before placement in jars. If sediment is stiff enough to sample with EnCore® or Terra Core® samplers for VOC analysis, follow the instructions contained in the EnCore® or Terra Core® SOPs, as applicable.
5. For channel sampling, be on the alert for submerged hazards (rocks, tree roots, broken bottles, sharps, snakes, drop-offs, loose silt and muck) which can make wading dangerous.
6. Follow the site safety plan designed for the specific nature of the site's sampling activities and locations.
7. Decontaminate all sampling implements and protective clothing according to prescribed procedures.

V. Attachments

Sediment Log Form.

VI. Key Checks and Items

- When working in flowing streams, start downstream and work upstream.
- As necessary and practical, log exact locations using permanent features, and gather GPS coordinates.
- Beware of hidden hazards in the water column.
- When sediment sampling at a location for the first time, bring several types of sampling equipment in case one does not work.

CH2MHILL

PROJECT NUMBER	SAMPLE NUMBER SHEET 1 OF 1

SEDIMENT LOG

PROJECT : LOCATION : DATE:

WEATHER:

METHOD AND EQUIPMENT USED :

LOGGER :

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (IN)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SEDIMENT DESCRIPTION COLOR, ODOR, MOISTURE CONTENT PARTICLE SIZE CHARACTERIZATION	COMMENTS UNUSUAL CHARACTERISTICS
0.5						
1.0						
1.5						
2.0						
2.5						

Sampler Signature: _____ Date: _____

G-2_Sediment SAMPLING FORMS2_jrm_jl.xls Updated May 2007

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STANDARD OPERATING PROCEDURE H-1

Preparing Field Log Books

I. Purpose and Scope

This SOP will provide standardized procedures and basic requirements for entering field data into log books during field activities. Log books are legal documents. They must be prepared following specific procedures and must contain required information to ensure their integrity and legitimacy.

II. Equipment and Materials

- Log book
- Indelible pen

III. Procedures and Guidelines

Properly completed field log books are a requirement of the work performed under the Navy CLEAN contract.

A. Procedures for Completing Field Log Books

1. Field notes are to be kept in bound, hard-covered logbooks, as well as task-specific logs. The pages are to be water-resistant and notes will be taken only with a water-proof, non-erasable permanent ink pen.
2. The inside cover of the log book generally should include:
    - Company name and address.
    - Log-holders name if log book was assigned specifically to that person.
    - Activity or location.
    - Project name.
    - Project manager's (PM's) name.
    - Phone numbers of the company, supervisors, emergency response, etc.
3. Daily entries will be made chronologically. Each page of the log book will have the date of the work and the note takers initials.
4. Information will be recorded directly into the field log during the work activity. Entries into the log should be as detailed and descriptive as possible so that a particular situation can be recalled without reliance on memory. Entries must be legible and complete.

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    - Phone numbers of the company, supervisors, emergency response, etc.
3. Daily entries will be made chronologically. Each page of the log book will have the date of the work and the note takers initials.
4. Information will be recorded directly into the field log during the work activity. Entries into the log should be as detailed and descriptive as possible so that a particular situation can be recalled without reliance on memory. Entries must be legible and complete.

5. Every line should be used to prevent later additions of text, or be marked through with a line, initialed and dated. Unused pages will be marked through with a line, the author's initials, date, and the note "Intentionally Left Blank."
6. If errors are made in the log book, cross a single line through the error and enter the correct information. All corrections shall be initialed and dated by the person performing the correction. If possible, all corrections should be made by the individual keeping the log.
7. Only information relevant to the subject project will be added to the log book.
8. The final page of each day's notes will include the note-takers signature and date.
9. Copies of the field notes generally should be sent to the PM or designee in a timely manner (generally by the end of each week of work being performed).

B. Information generally to be Included in Field Logs

1. Use the left side border to record times and the remainder of the page to record information.
2. General project information will be recorded at the beginning of each field project; the project title, project number, staff, scope of the day's work and weather conditions (note changes).
3. Subcontractor Information: Record name of company, names and roles of subcontractor personnel, list type of equipment being used and general scope of work. List start and stop times, and quantities of billable line items accomplished.
4. Technical and Project Information: Describe the details of the work being performed. The project SAP will describe the specific activities to be performed and may also list requirements for note taking. Discuss note-taking expectations with the PM prior to beginning the field work.
5. Any conditions that might adversely affect the work or data obtained.
6. Time: Keep a running time log explaining field activities as they occur throughout the day.
7. Tail Gate Safety Talks: Record topics discussed.
8. Standard Health and Safety Procedures: Record level of personal protection being used (e.g., level D PPE). Also record other required health and safety procedures as specified in the project specific health and safety plan.
9. Instrument Calibration: Record calibration information for each piece of health and safety/field equipment if not recorded elsewhere.
10. Personnel: Record when personnel and visitors enter and leave the site.
11. Communications: Record all communications that impact performance of the project.
12. Deviations from the SAP: Record deviations from the SAP; document the reasons and communications authorizing deviations.

13. Heath and Safety Incidents: Record all health and safety incidents in detail, immediately reporting them to the field team leader (FTL) and PM.
14. Problems and Corrective Actions: Clearly describe problems encountered during the field work and the corrective actions taken.
15. Sampling Information: Specific information that will be relevant to most sampling jobs includes the following:
    - Description of the general sampling area – site name, buildings and streets in the area, etc.
    - Station/Location identifier.
    - Description of the sample location – estimate location in comparison to two fixed points – If location not already identified on a map or figure, draw a diagram in the field log book indicating sample location relative to these fixed points – include distances in feet.
    - Sample matrix and type.
    - Sample identifier, date and time.
    - Information on how the sample was collected – distinguish between "grab," "composite," and "discrete" samples.
    - Number and type of sample containers collected.
    - Record of any field measurements taken (i.e. pH, turbidity, dissolved oxygen, and temperature, and conductivity).
    - Parameters to be analyzed for, if appropriate.
    - Descriptions of soil samples and drilling cuttings can be entered in depth sequence, along with PID readings and other observations. Include any unusual appearances of the samples.
    - If the PM specifies, some of the above can be entered in GBC or spiral bound field sampling books printed specifically for the sampling task instead of in the hard cover log book.

C. Suggested Format for Recording Field Data

1. Use tables to record sampling information and field data from multiple samples. Keep data organized for easier review.
2. Sketch sampling locations, construction sites, and other pertinent information.
3. Sketch well construction diagrams or use well-completion logs.

STANDARD OPERATING PROCEDURE H-4

Chain-of-Custody

I. Purpose

This SOP provides standardized procedures for completing chain of custody (COC) forms. Any project required deviations from standard operating procedures (SOPs) will be provided in site specific sampling and analysis plans (SAPs).

II. Scope

This procedure describes the steps necessary for transferring samples through the use of a COC. A COC is required for the tracking and recording of samples collected during program activities. Use of the COC creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over regional- or site-specific requirements.

III. Definitions

Chain-of-Custody Record - A COC is a printed form that accompanies a sample or group of samples as custody is transferred from one custodian to another custodian. One copy of the form must be retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes the custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and is secured to prevent tampering.

Sample - A sample is physical evidence which is representative of conditions at the point and time that it was collected.

IV. Procedures

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, recordkeeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

A. Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When *in situ* measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which may be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s),
- Contract Task Order (CTO) Number,
- Project Sample Number,
- Sample location or sampling station number,
- Date and time of sample collection and/or measurement,
- Field observations,
- Equipment used to collect samples and measurements, and
- Calibration data for equipment used

Measurements and observations shall be recorded using waterproof ink.

1. Sample Label

Samples removed and transported from the sample location to a laboratory or other location for analysis will be collected into laboratory provided containers and labeled. Sample labels will include:

- Project - CTO Number.
- Sample Identification - The SAP/SSP I.D. provided for the sample.
- Date - Day, month, and year of sample collection.
- Time - A four-digit number in the 24-hour format at time of collection.
- Medium - Water, soil, sediment, sludge, waste, etc.
- Sample Type - Grab or composite.
- Preservation - Type of preservation.
- Analysis – Type of analysis to be performed (e.g., VOC).

- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

B. Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under COC procedures until it is in the custody of the analytical laboratory and has been stored or disposed of.

1. Field Custody Procedures

- Care must be taken to ensure that the sample information on the label matches the COC exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- Sample labels shall be completed for each sample, using waterproof ink.

2. Transfer of Custody and Shipment

Samples are accompanied by a COC. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the COC. This documents sample custody transfer from the sampler to the analyst in the laboratory. The COC is shipped as described below:

- Place the original (top, signed copy) of the COC in a plastic zipper-type bag or other appropriate sample-shipping package. Retain the copy with field records.
- Sign and date two custody seals, 1-inch by 3-inch white paper labels with black lettering and an adhesive backing. The custody seals are part of the COC process and are used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seals across the shipping container opening on diagonally opposite corners, so that one would be broken if the container were to be opened.
- Complete other carrier-required shipping papers.

Any corrections are made by drawing a line through, initialing and dating the change, then entering the correct information. Erasures are not permitted.

As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment then signs and dates the COC, completing the sample transfer process. It is then the laboratory's responsibility to maintain custody records throughout sample preparation and analysis.

V. Quality Assurance Records

Once samples have been packaged and shipped, the COC copy and airbill receipt become part of the QA record.

VI. Attachments

Chain of Custody Form.

VII. References

USEPA. *User's Guide to the Contract Laboratory Program*. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

Vieques ERP
CH2M HILL
Chain of Custody Form

Project Site		AOC E			Number of Containers	Analysis Requested													Project No.
Project Manager		Brett Doerr																	
Contact Tel No.		757-289-9246 (Adrienne Jones)																	Lab Batch/SDG ID
Contact Address		4350 W. Cypress Street, Suite 600, Tampa, FL 33607																	
Lab Name																			Lab Tel No./Fax No.
Lab Contact																			
Lab Address																			
Item	Sample ID	Station ID	Matrix	Date & Time Collected		MET_SO/CN	PCB_SO	PEST_SO	SVOC_SO	TL_SO	TOC_SO	TPH_SO_DRO/ORO	TPH_SO_GRO	VOC_SO	GRAIN_SIZE	TPH_W_GRO	VOC_W		Comments
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			

Sampled By:	Date/Time:	Custody Seal: Y / N Relinquished By:	Date/Time:
Shipped Via: UPS FedEx Hand Other (Please specify):			
Samples Temperature and Condition Upon Receipt (for lab's use):			
Received By:	Date/Time:	Custody Seal: Y / N Relinquished By:	Date/Time:
Received By:	Date/Time:	Custody Seal: Y / N Relinquished By:	Date/Time:
Remarks:			

Updated May 2007

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STANDARD OPERATING PROCEDURE H-5

Packaging and Shipping Procedures for Samples Not Considered Dangerous Goods

I. Purpose and Scope

The purpose of this guideline is to describe the packaging and shipping of samples of various media to a laboratory for analysis. This standardized procedure only covers samples of sufficiently low concentration as to not be considered dangerous goods for purposes of shipping.

II. Scope

The guideline only discusses the packaging and shipping of samples that are anticipated to have sufficiently low concentrations of chemical constituents as to not be considered dangerous goods when being shipped. Whether or not samples should be classified as low-concentration or otherwise will depend upon the site history, observation of the samples in the field, odor, and photoionization-detector readings.

If the site is known to have produced high-concentration samples in the past or the sampler suspects that high concentrations of contaminants might be present in the samples, then the sampler should conservatively assume that the samples cannot be classified as low-concentration. Samples that are anticipated to have medium to high concentrations of constituents should be packaged and shipped following procedures for dangerous-goods shipping specified by the intended shipper (e.g., Federal Express).

III. Equipment and Materials

- Coolers
- Clear tape
- Duct tape
- “This Side Up” labels
- “Fragile” labels
- Ziplock bags or bubble wrap
- Ice
- Chain-of-Custody form (completed)
- Custody seals

IV. Procedures and Guidelines

A. Sample Packing

1. Prepare coolers for shipment:
   - Tape drains shut from the inside of the cooler.
   - Affix "This Side Up" labels on all four sides and "Fragile" labels on at least two sides of each cooler, if available.
   - Place mailing label with laboratory address on top of coolers.
   - As necessary (helpful for large bottle ware), fill bottom of coolers with about 3 inches of bubble wrap.
2. Arrange decontaminated sample containers in groups by sample number. Consolidate volatile organic compound (VOC) samples into one cooler to minimize the need for trip blanks.
3. Affix appropriate adhesive sample labels to each container. Protect with clear label protection tape.
4. Seal each set of sample bottles within a separate water proof zipper-type plastic bag and bubble wrap, if available. Make every attempt to ensure the samples are water proof. Double bag Encore VOC samples and soil samples. Sample label should be visible through the bag.
5. Place two large plastic bag liners, one inside the other, openings up. Arrange sample containers in liners so bags do not touch each other. Temp blank should go on the bottom of the cooler, in an area where it can be completely surrounded by ice.
6. If ice is required to preserve the samples, use at least two full bags and place on and around the containers.
7. Fill remaining spaces with bubble wrap or ice as required and add the laboratory provided trip blank.
8. Close the inside liner first by twisting the opening to the bag liner closed, allowing as much air to escape as possible. Zip-tie the bag closed and tie the end into a knot. Do the same to the second liner being sure to remove as much air as possible.
9. Complete and sign COC (or obtain signature) and indicate the time and date it was relinquished to Federal Express or the courier. Place into a zip-type bag and tape it to the inside of the lid of the cooler.
10. Close lid and latch.
11. Carefully peel custody seals from backings and place intact over lid openings (right front and left back). Cover seals with clear protection tape.
12. Tape cooler shut on both ends, making several complete revolutions with tape. Do not cover custody seals.

13. Relinquish to Federal Express or to a courier arranged with the laboratory. Scan airbill receipt and COCs to the sample documentation coordinator (or mail if scanner not available) along with the other documentation.

B. Medium- and High-Concentration Samples

Medium- and high-concentration samples are packaged using the same techniques used to package low-concentration samples, with several additional restrictions. The sample handler must refer to instructions associated with the shipping of dangerous goods for the necessary procedures for shipping by Federal Express or other overnight carrier.

V. Attachments

None.

VI. Key Checks and Items

- Be sure laboratory address is correct on the mailing label.
- Pack sample bottles carefully, with adequate bubble wrap or other packaging and without allowing bottles to touch.
- Be sure there is adequate ice.
- Include COC.
- Affix custody seals.

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STANDARD OPERATING PROCEDURE H-6

Equipment Blank Preparation

I. Purpose and Scope

This document provides standardized procedures for collecting equipment blanks used to determine whether decontamination procedures are adequate during sampling. Any project required deviations from standard operating procedures (SOPs) will be provided in site specific sampling and analysis plans (SAPs). The general protocols for preparing the blanks are outlined. The actual equipment to be rinsed will depend on the requirements of the specific sampling procedure.

II. Equipment and Materials

- ASTM Type II reagent water with analysis certification (blank water).
- Sample bottles with preservatives according to the SAP.
- Gloves.

III. Procedures and Guidelines

A. Decon all sampling equipment according to "Decontamination of Personnel and Equipment" SOP.

B. For volatile organic compound (VOC) analysis from the surfaces of equipment other than pumps, pour blank water over one piece of equipment and into three 40-ml vials as per VOC water sampling procedure.

C. For non-VOC analyses, one aliquot is to be used for equipment. Pour blank water into the sampling bowl and other equipment so surfaces which previously contacted the sample are now in contact with the blank water. Pour blank fluid from pan into the appropriate sample bottles.

D. For pumps, run an extra gallon of blank water through the pump while collecting the pump outflow into appropriate containers. If a pump with disposable tubing is used, put new tubing onto the pump to collect the equipment blank.

E. Document and ship samples in accordance with the procedures for other samples.

IV. Attachments

None.

V. Key Checks and Items

- Wear gloves.
- Do not use any disposable or non-decontaminated equipment to prepare blank.
- Use ASTM-Type II reagent water with analysis certification.

Aerial Magnetometer Survey Operations Plan
Former Vieques Naval Training Range (VNTR)
Vieques, Puerto Rico

Prepared by
Sky Research, Inc.
445 Dead Indian Memorial Road
Ashland, OR 97520

Submittal Date: November 3, 2008
Version 1.0

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ACRONYMS

3D	Three-Dimensional
AGL	Above Ground Level
AMS	Aerial Magnetometer Survey
AMSOP	Aerial Magnetometry Survey Operations Plan
AOI	Area of Interest
ATC	Air Traffic Control
CD	Compact Disc
cm	centimeter(s)
DAS	Data Acquisition Software
dBA	Decibels (on the A Scale)
DFOW	Definable Features of Work
DQO	Data Quality Objective
DVD	Digital Video Disc
ETA	Estimated Time of Arrival
F	Fahrenheit
FAA	Federal Aviation Administration
GIS	Geographic Information Systems
GPS	Global Positioning System
HASP	Health and Safety Plan
HeliMag	Helicopter Magnetics
Hz	Hertz
IVS	Instrument Validation Survey
LiDAR	Light Detection and Ranging
m	meter(s)
MEC	Munitions and Explosives of Concern
mm	millimeter(s)
NGS	National Geodetic Survey
nT	nanoTesla
OSHA	Occupational Health and Safety Administration
pdf	Portable Document Format
PIC	Pilot in Command
PPE	Personal Protective Equipment
QC	Quality Control
QCP	Quality Control Plan
RTK GPS	Real Time Kinematic Global Positioning System
SAR	Search and Rescue
SKY	Sky Research, Inc.
SOP	Standard Operating Procedure(s)
SSM	Site Suitability Model
USACE	US Army Corps of Engineers
UXO	Unexploded Explosive Ordnance
VNTR	Vieques Naval Training Range

1.0 INTRODUCTION

This Aerial Magnetometer Survey Operations Plan (AMSOP) describes the planned airborne geophysical survey utilizing helicopter magnetics (HeliMag) in support of the Expanded Range Assessment and Phase II Site Inspection of the Former Vieques Naval Training Range (VNTR) at Vieques, Puerto Rico. This work is being performed by Sky Research Inc (SKY), under contract to CH2M Hill on behalf of the Department of the Navy, Naval Facilities Engineering Command Atlantic. The explicit purpose of this project is to identify areas containing high densities of ferrous metallic objects on the surface and/or subsurface. At VNTR, the presence of ferrous metallic objects in high densities is suggestive, unless explained by known sources (such as buildings or utility-related structures), of an area of interest (AOI) that might contain munitions and explosives of concern (MEC), including unexploded ordnance (UXO). The overall objective of the aerial magnetometer survey (AMS) is to identify any existing AOI to assist in prioritizing munitions response actions at VNTR. Results of the AMS are not intended to be used for eliminating areas from the possibility of containing MEC.

2.0 SITE DESCRIPTION

2.1 General

Vieques Island has a land area of approximately 33,000 acres, and is located in the Caribbean Sea approximately 7 miles southeast of the eastern coast of the main island of Puerto Rico (Figure 1). The former ~~Naval~~ facilities are located on the eastern one-third of the island. The planned aerial survey area is presented in Figure 1.

2.2 Geologic Conditions

Geological information and site observations suggest that the majority of the site consists of geologic strata with low ferrous-mineral content, which should afford favorable conditions for a survey of magnetic material.

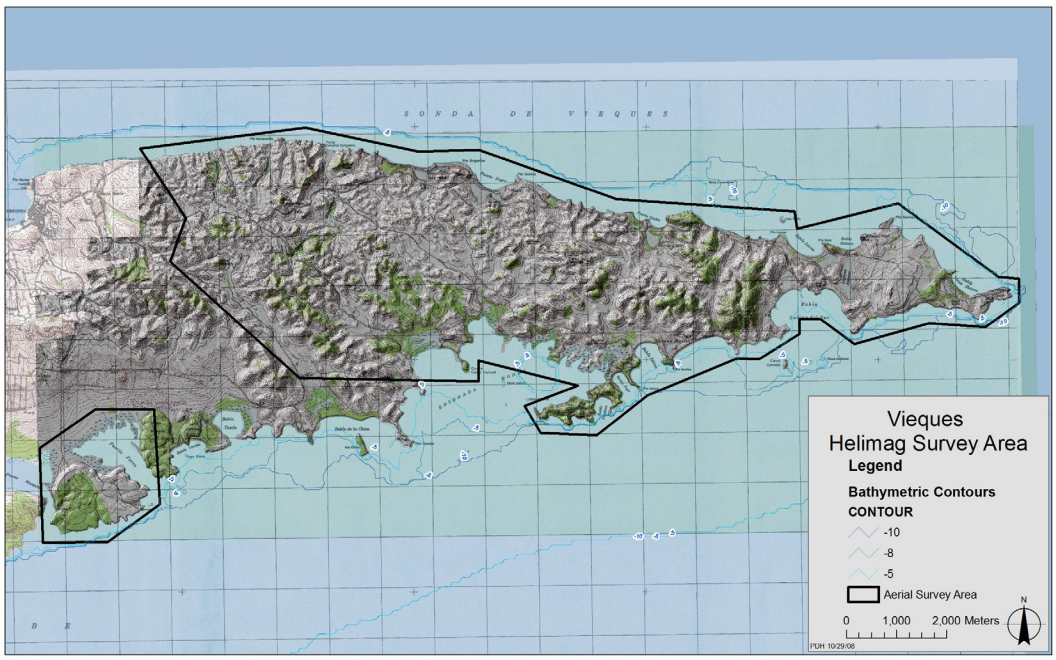

Figure 1. Proposed VNTR HeliMag survey boundary.

2.3 Topography and Vegetation

Topography and vegetation are the primary determinants of the HeliMag survey altitude. In 2005, a Light Detection and Ranging (LiDAR) survey was performed (CH2M Hill 2007) for the VNTR project site, yielding high-resolution topographic and vegetation height data. From this data, a Site Suitability Model (SSM) was created to identify areas of the site where terrain and vegetation would reasonably allow for a helicopter-based magnetometer array system to be flown at a height that could detect concentrations of ferrous metallic items indicative of potential target areas. Figure 2 shows the overall 15,200-acre (approximate) area selected for the AMS surveys, within which it is anticipated that, based on the SSM, approximately 65 percent of the site can be covered at an instrument height of approximately 5 meters (m) or less above ground level (AGL) and nearly 50 percent at 4 m AGL or less. At this height, approximately 90 percent of the

155-millimeter (mm) projectiles lying on the ground surface would be detected. Larger ordnance sizes and groupings of ordnance would be detected at a higher confidence and at further distances (or depths).

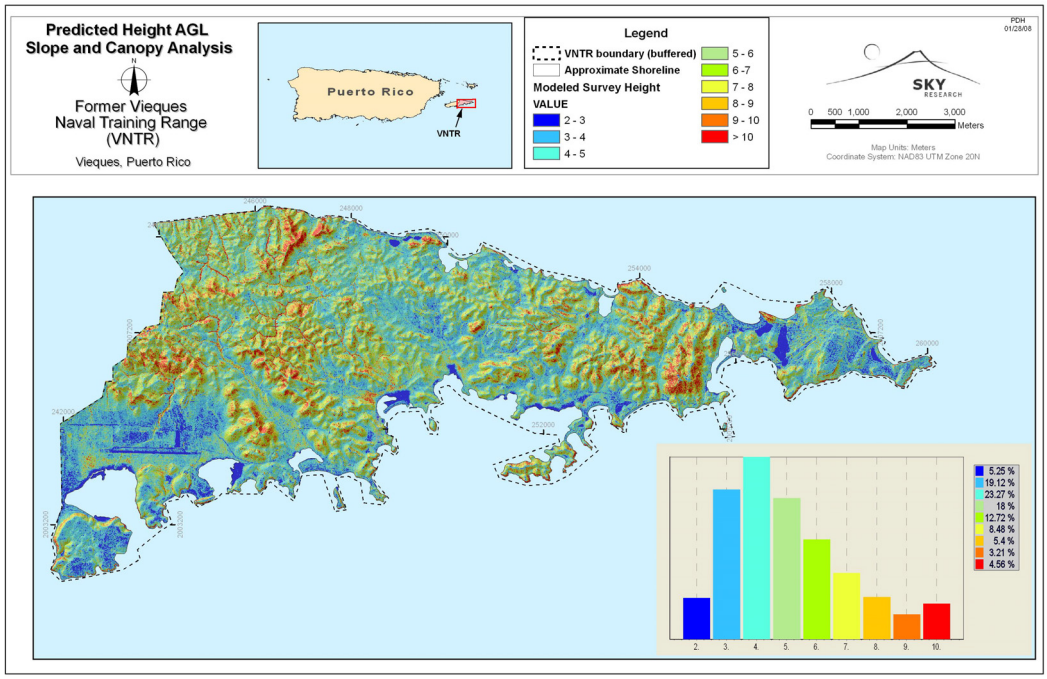

Figure 2. Predicted VNTR HeliMag survey sensor height (m AGL) based upon LiDAR-derived terrain and vegetation models.

2.4 Anthropogenic Features Potentially Affecting Geophysical Investigations

Anthropogenic features such as buildings, power lines, fences and pipelines generally have characteristic magnetic signatures that mask and/or distort the response of MEC-like objects. After data are collected, the effects of these surface and subsurface features are routinely identifiable in the data, and manifest as linear, curved or very large anomalies. In some cases, the deleterious effects of these features on the survey results can be mitigated during the processing of the data. However, demarcation of the affected areas as areas where the potential for MEC has not been investigated is required. Very few anthropogenic features are anticipated within the VNTR survey area.

2.4.1 Site-Specific Dynamic Events Affecting Geophysical Investigations

Dynamic events (rain, lightning, solar flares, etc.) may temporarily impact geophysical data collection and/or data quality. Procedures for these anticipated events are as follows:

- **Rain**: Rain is a hazard to crew and equipment primarily due to its effect on visibility conditions. During periods of rain, the Pilot in Command (PIC) will assess the intensity and determine when or how to proceed with survey operations. When surveying stops, the field activity log will reflect the conditions and reasons for the stoppage. Once the rain ends, and time permitting, the survey will resume.

- **Lightning**: Lightening is a severe hazard to the health and well-being of field crews. Site personnel and equipment will take shelter in a safe area. Geophysical team members will make the determination that lightning is present, annotate the survey activities log and shut down field operations until the threat passes.
- **High Winds**: High winds present a safety hazard to airborne survey operations. The PIC will determine if hazardous wind conditions exist and will terminate airborne survey activities. Once workable conditions return, work will resume.

2.5 Overall Accessibility and Impediments

The site is easily accessible by air, and no known site accessibility issues exist. U.S. Fish and Wildlife Service refuge requirements for conducting this survey will be satisfied prior to mobilization, and all designated guidelines will be observed during the survey.

2.6 Potential Worker Hazards

All site personnel will adhere to the practices, procedures, and training and monitoring requirements mandated by the Health and Safety Plan (HASP).

3.0 AIRBORNE GEOPHYSICAL SURVEY

3.1 Geophysical Survey Objective

SKY will utilize 100% coverage surveys for the detection of surface and subsurface ferrous material consistent with possible MEC items of interest at this site. These data will be used to characterize the site with respect to the density distribution of ferrous material across the site.

3.2 Geophysical Equipment

3.2.1 Helicopter Survey Platform

SKY will deploy a helicopter borne magnetometer array commonly referred to as the Helimag system. The HeliMag sensor booms are constructed from Kevlar and carbon fiber, making them lightweight and durable. The HeliMag platform is equipped with seven Geometrics G-822 cesium vapor magnetometers spaced 1.5 m apart, two Trimble MS750 real-time kinematic global positioning systems (RTK GPS) receivers that provide positions and platform attitude at 10 Hertz (Hz), with up to four altimeters for recording the altitude of the platform. The HeliMag system utilizes a state of the art Data Acquisition System (DAS) that logs data at 400 Hz. The DAS has integrated pilot guidance software that displays the platform position and altitude information relative to the pre-determined flight lines.

3.2.2 Cesium Vapor Magnetometers

Magnetometers are used to detect perturbations in the Earth's magnetic field caused by ferrous metallic objects. The Geometrics G-822 and G-858 magnetometers are optically pumped cesium vapor instruments that measure the intensity of the Earth's magnetic field in nanoTeslas (nT). Anomalies in the Earth's magnetic field are caused by remanent or induced magnetism. Remanent magnetism is caused by naturally occurring magnetic materials. Induced magnetic anomalies result from induction of a secondary magnetic field in a ferromagnetic material (e.g., pipes, drums, MEC) by the Earth's magnetic field. The shape and amplitude of an induced magnetic anomaly over a ferromagnetic object depend on the geometry, size, and depth. Induced magnetic anomalies over buried objects generally exhibit an asymmetrical, south high/north low, signature. Magnetic anomalies caused by buried metallic objects have dimensions much greater than the dimensions of the objects themselves.

3.2.3 Geophysical Positioning Methods

SKY uses Trimble MS750 RTK GPS receivers to accurately position the geophysical sensor data. GPS technology uses satellite-based broadcasts to derive the antenna's 3-dimensional (3D) position on the surface of the Earth. Using a local GPS base station to provide real-time differential corrections via a radio link, accuracies of 2 centimeters (cm) are achieved with this technology. The DAS uses the GPS time message and highly precise timing pulse to discipline its internal clock to GPS time. All sensor data are time stamped with GPS time to be used as the basis for merging sensor measurements based upon their time of applicability.

To use GPS on-site, SKY will employ following actions:

- SKY will coordinate with CH2M Hill personnel to locate and gain access to existing benchmarks.
- SKY will establish a temporary monument to deploy a local GPS base station if National Geodetic Survey (NGS) monuments do not exist.
- SKY will use radio repeaters to extend the transmission range of the real-time corrections provided by the local GPS base station.
- SKY will establish temporary control points to perform positions accuracy tests.

All geophysical data collection activities follow Sky Research's Standard Operating Procedures (SOP).

3.3 Personnel

3.3.1 Airborne Survey Geophysicist

The Airborne Survey Geophysicist has overall responsibility for the day-to-day implementation and management of all geophysical activities required for the work effort. In addition to those duties, they will work with the Project Manager (Section 4.2.1.1) to ensure a successful project. The Airborne Survey Geophysicist coordinates all activities associated with the collection, processing, and analysis of geophysical data; reviews all data processing steps, including filtering, anomaly identification, data modeling and dig lists; and reviews all ground truth data for anomaly correlation and correctness.

3.3.2 Helicopter Pilot

The Helicopter Pilot-In-Charge (PIC) is responsible for piloting the aircraft in a safe and efficient manner. The PIC has complete control over all aircraft-related operations and emergency response activities and requirements. The PIC has the authority to abort any flight, as well as to deviate from survey specifications (speed, altitude, and/or flight duration) for safety purposes. SKY will utilize two helicopter pilots for this operation to ensure a maximum data collection capability while maintaining maximum in-air safety.

3.3.3 Sensor Operator

The Sensor Operator operates the onboard instrumentation and is responsible for the proper execution of HeliMag activities associated with data collection.

3.3.4 Ground Support Team Member

The Ground Support team member is responsible for emplacement of calibration targets, set up of GPS base stations and repeaters, delivery of fuel, and flight following. The Ground Support team member is a proficient user of the GPS survey equipment and has been trained in the proper procedures for the above activities.

3.3.5 Data Processor

The Data Processor is responsible for processing all the geophysical data using the site specific data processing procedures and filing all the appropriate data processing paperwork. The person does not need to be on-site to perform these tasks.

3.3.6 Quality Control Geophysicist

The Quality Control (QC) Geophysicist is responsible for ensuring all data meet the quality objectives of the project. They will file all the appropriate QC paperwork. This person does not need to be on-site to perform these tasks.

3.4 Data Acquisition

3.4.1 Logistics

3.4.1.1 Base of Operations

The helicopter will base out of Antonio Rivera Rodriguez Airport, Isla de Vieques, Puerto Rico (VQS). Normal Air Traffic Control (ATC) communications will be used during the takeoff and climb out phase of the data collection flights on the island. The pilot will be in contact with ATC and receive VFR traffic advisories during the flights.

Daily operations will be based out of Camp Garcia in Central Vieques, utilizing the CH2M Hill trailer and support facilities. A test strip that is required to be flown daily, referred to as the Validation Lane, will be established at Camp Garcia closed runway if suitable.

~~3.4.1.2 Crew Accommodation~~

~~The Helimag crew will be staying at the Crow's Nest Hotel, located at Carr. #201 K.M.16 BO, Florida Vieques 00765.~~

3.4.1.3 Fuel Supply/Remote Refueling

Fuel will be provided through the Fixed Base Operator (FBO) Million Air San Juan based at the VQS Airport. Million Air will also provide a 2,200 gal fuel truck to allow refueling at approved Re-Fuel/HeliMag staging sites as follows:

Western HeliMag Sectors:	VQS Airport
Central HeliMag Sectors:	Camp Garcia
Eastern HeliMag Sectors:	OP-1

A map showing the locations and distances from sites is presented in Figure 3.

Figure 3. Proposed Helimag remote staging/refueling sites

The Sky Helimag team is experienced in remote refueling, 'hot refueling', and spill avoidance. The standard operating procedures for refueling the aircraft are as follows:

1. Landing Procedures and Safety Protocols

The following safety procedure will be followed during all helicopter ground operations.

- The pilot is in 2-way radio communication with all ground operations.
- During landing and takeoff maneuvers, ground personnel will remain well clear of the aircraft. If proximity to the helicopter is necessary, proper eyewear is required to protect against flying debris caused by rotor downwash.
- Only personnel essential to the survey operation may approach the aircraft.
- Ground support personnel will wear proper Personal Protective Equipment (PPE), including (but not limited to) boots and safety glasses.
- Proper hearing protection is to be worn by personnel working near the aircraft while the engine is running.
- Never approach the rear of the aircraft.
- Never approach or leave the aircraft without the pilot's knowledge – always approach and leave the aircraft within sight of the pilot.

2. Refueling Procedures

Designated ground personnel will be assigned to support the refueling operations. Helicopter fuel will be stored in tanks stored on a portable platform (truck or otherwise). When the fuel trailer is not in use it will be locked as appropriate.
The following procedure will be followed during all refueling activities:

- Fueling is to be performed by qualified personnel only. Non-qualified personnel must stay clear of the aircraft during fueling operations.
- 'Hot Refueling' is authorized where approved and where qualified Sky Research or other qualified refuel personnel are available. All crews and personnel involved in the Hot Refuel procedure must be familiar with the Emergency Aircraft Shut-Down procedure and must (if they are Sky Research personnel) be wearing full PPE. The helicopter shall remain running at ground idle with the pilot at the flight controls during all Hot Refuel operations.
- All geophysical survey equipment is to be turned off during fueling operations.
- Helicopter will be electrically bonded to the fueling trailer prior to the beginning of fueling operations.
- Fueling team will consist of two personnel, one trailer pump operator, and one fuel nozzle operator.
- Fueling personnel will wear proper PPE at all times, including but not limited to sturdy boots, safety glasses, hearing protection, and appropriate hand protection.
- A 20 lb B-C class fire extinguisher will be designated for helicopter operations, and will be located with the fuel tanks.
- Fueling personnel will have absorbent diapers available for spill cleanup.

3.4.1.4 Maintenance Support

Maintenance support on the island will be provided by internal, company, licensed Airframe and Powerplant mechanics with inspection authorization.

3.4.2 Production Rates

Geophysical mapping production rates are highly variable and depend on several factors, including airspace, topography, vegetation, site access, proximity of survey area, lane spacing, and weather conditions. Typical HeliMag production rates are 400 to 600 acres per day (assuming 8 flying hours/day). Local site conditions such as weather, terrain, and ferry distances are the prime determinants of productivity. Current knowledge of the expected conditions at VNTR indicates that the productivity should fall within these norms.

3.4.3 Data Resolution and Density

Data resolution and density will meet Data Quality Objectives (DQOs) defined by the project for spatial registration, down-line and along-line spacing, intrinsic noise levels, and survey velocity. The HeliMag system flies at nominal survey speeds of 15–30 m per second (approximately 30–60 knots). The data processor monitors the data densities and

flags any areas for recollection that do not meet the project objectives. When data densities do not meet the objectives, the Airborne Survey Geophysicist will notify the field crew and correct the problem.

3.4.4 Instrument Validation Survey

An Instrument Validation Survey (IVS) test lane will be established to verify that the system meets the DQOs described in Section 4.4. This test lane will be used for initial instrumentation validation as well as daily monitoring of system performance as described in the Quality Control Plan (Section 4). The validation lane will be nominally 500 m in length. Standardized test items will be placed at intervals along this lane, and their precise 'ground truth' locations will be measured using established surveying techniques. The HeliMag detection/location performance will be assessed and monitored by comparison of the system results with the ground truth positions of the test items.

3.4.5 Equipment Warm-Up

Most geophysical instrument readings drift for a couple of minutes after starting up. All sensors will warm up for at least 5 minutes prior to testing or data collection. Each time the instrument starts (e.g., at the start of the day, after breaks, refueling, etc.), this procedure will be followed.

3.4.6 Record Sensor Position

Proper sensor geometry is important to the spatial registration of data during processing. The sensor positions relative to the helicopter and master GPS antenna are engineered and recorded prior to the survey system installation. These spatial relationships remain fixed. At the beginning of the survey, the SKY field crew will perform a response test under each sensor to ensure that the sensors cables are connected to the appropriate data input channel. This test will be repeated every time the system is disassembled and reassembled.

3.4.7 Time Alignment Validation

All instruments have a built-in latency between the measurement and the output of the reading. To properly position geophysical data, the time of applicability of the positional data must be aligned with that of the geophysical data. The SKY HeliMag system precisely time stamps all recorded data and the data processing software automatically aligns the data appropriately. The time alignment is verified by collecting data along the validation lane in two reciprocal directions. Proper time alignment is validated by comparison of survey responses from these two reciprocal lines to ensure that the magnetic peaks are aligned. This test is performed at the start and end of each survey day as part of the IVS lane test. If the Airborne Survey Geophysicist or Project Manager terminates field operations early due to weather conditions, the end-of-day test may not be performed. The Validation Lane Survey Log will document the results of this test.

3.5 Data Processing

SKY uses its custom in-house software called SkyNet to transcribe, filter, decimate, and position the airborne geophysical data. The output from SkyNet is an ASCII xyz file that can then be imported into the Geosoft Oasis Montaj geophysical processing environment.

Oasis is used to visualize the data and apply advanced processing where required. Anomaly selections may be performed in the Oasis environment or in the proprietary UXOLab environment. UXOLab is a fully-functional, validated, MATLAB-based data processing package. The following sections describe the processing steps used by SKY as part of the site-specific data processing and analysis. The Data Processing Report documents the parameters used and statistics from the review and processing steps.

3.5.1 Data Transcription

The raw data are transcribed from their native data file formats into ASCII xyz files using SkyNet. At this point, the geophysical data are subjected to a lowpass/notch filter, decimated to a sample rate of 100 Hz and assigned 3D positions based upon the GPS master antenna position, aircraft attitude and the system geometry.

3.5.2 Initial Data Review

The Data Processor performs the initial review of the geophysical data. If problems exist, the Data Processor will notify the Project Geophysicist. The Project Geophysicist will assess the problem(s) and make adjustments to the field operations or data processing as needed to ensure quality data collection. The sections below detail the initial review of each data type.

3.5.3 Geophysical Data

The initial review of geophysical data insures that the data are within a reasonable range, are free from dropouts/spikes, and timing errors and otherwise appear to be valid. A qualified data processor reviews the summary and visually inspects the data. The Data Processing Report documents any discrepancies.

3.5.4 Positional Data

The initial review of positional data involves checking line profiles for position dropouts/spikes. The Data Processing Report documents any discrepancies.

3.5.5 Sensor Data Filtering

Spatial and/or time base filters are used to remove long wavelength signal from the dataset. Some of the sources of this long wavelength response are diurnal variations, geologic response, sensor heading errors, and aircraft maneuver noise. The specific parameters of the filters are to be determined by site conditions such as geologic response and survey altitude above ground.

3.5.6 Spike Removal

When data spikes are numerous, this indicates a problem with the instrument. Sporadic data spikes are typical but usually occur infrequently. Running a spike rejection function removes data points that resemble spikes. The Airborne Survey Geophysicist will set the maximum acceptable jump parameter for the spike rejection as part of his review of the processing procedures. Typically, this value is set to 100.

3.5.7 Gridding Method and Search Criteria

To convert the data into an image map, an interpolation algorithm will convert the XYZ data into an evenly-spaced grid image at 1 m intervals. The data processor will review the grids to determine the completeness and accuracy of prior data manipulation steps.

3.5.8 Color Distribution Level Selection

The Airborne Survey Geophysicist will select color distribution levels (thresholds, min/max, etc.) that accentuate the areas/anomalies of interest in the anomaly density maps provided for each block. The same color scheme will be used for each block, in order to avoid confusion and to enhance the ability to compare the anomaly densities across the site easily.

3.5.9 Total Magnetic Field Maps

The final gridded data are an interim product of the HeliMag data processing. In order to aid in visualization of the magnetic response across the site, the gridded data will be presented in map form. The total magnetic field maps will be annotated to contain the following information:

- Site name
- Map product
- Survey location
- Vertical scale bar
- Project coordinate system grid and labels

3.6 Data Analysis

After processing, anomalies in the final total magnetic field data that are consistent with the magnetic response of MEC (with respect to size, shape, and special extent) are selected. These anomalies are then used as the basis for creation of anomaly density maps. These density maps provide a visual representation of the spatial distribution of ferrous metal targets. High density anomaly clusters are identified as areas of interest.

3.6.1 Anomaly Selection and Decision Criteria

For each dataset, the Airborne Survey Geophysicist will assess each of the following factors prior to generating an anomaly list:

- Geophysical response (amplitude) of targets of interest, as measured in the calibration lane;
- The local geologic/anthropologic background conditions after filtering;

Based upon the site conditions, the Airborne Survey Geophysicist will elect to select anomalies using automated or manual techniques. Under most conditions, automatic picking algorithms perform well. However, in areas with challenging background magnetic response or a great deal of anthropogenic clutter, manual selection techniques are required. When automated techniques are used, a manual review of the data and targets will be used to locate additional anomalies or to delete anomalies. The Data

Processor and QC Geophysicist will delete anomalies if they are obviously due to cultural features or are obviously outside of the size/depth/shape envelopes of the targets of interests.

3.6.2 Target Analysis/Classification

Each selected anomaly will be analyzed. The target analysis algorithms have been adapted to run within the University of British Columbia MATLAB UXOLab software environment developed specifically to conduct target analysis and picking. Within the analysis environment, the processor selects mapped anomalies interpolated from the magnitude-corrected XYZ sensor data points. The software extracts sensor data points associated with the selected target. Each sensor reading is an input datum used in a six-parameter, iterative calculation to derive the parameter values that describe a dipole model that best fits the observed data. These parameters include dipole position (3 dimensions), dipole angle (2 angles) and dipole magnitude (size). These derived dipole parameters are then compared to training datasets developed from inert ordnance to perform target classification. Final outputs from this step are XYZ points in ASCII format with associated dipole parameters and target classification declarations.

3.6.3 Target Density Distribution Analysis

Target density distribution maps will be the final product of the HeliMag data processing. To aid in visualizing the distribution of metallic items across the site, a density raster is computed using a 100 m radius neighborhood kernel that assigns anomaly densities (in anomalies per hectare) to each cell in the raster. The target classification results are used to provide refined target lists and density distributions based upon site-specific goals and conditions.

Although it is not possible to determine which specific anomalies are due to the targets of interest, it is possible to refine the list by excluding some anomalies based upon the character or 'features' of the anomaly. Each anomaly is characterized by performing a dipole fit analysis. A magnetic dipole model can be defined with six parameters. These parameters define the position, the orientation, and the size of the dipole. An iterative process is used to determine the values for these parameters that describe the dipole model that best fits the observed data for each anomaly. These parameters are then used as 'feature' estimates for each target (e.g., the dipole model positions are accurate estimates of the object position and depth of each target). The target list can then be refined by excluding anomalies based upon one or more of these features. Dipole size and orientation with respect to the Earth's field are the most useful features for refining targets lists.

The utility of the dipole orientation relative to the Earth's field is as follows: The magnetic response of ferrous material has two sources, 'induced' magnetism and 'remanent' magnetism. Objects that have undergone mechanical shock (such as ordnance that have been fired) will become demagnetized – i.e., the remanent magnetization is removed. In addition, for ordnance-shaped objects 'induced' magnetic dipoles are aligned within 60 degrees of the Earth's magnetic field vector, while remanent dipole responses are not similarly constrained. Thus targets with dipole orientations greater than 60

degrees from parallel with the Earth's field can be assumed to have significant remanent magnetization and, as such, are not likely to be associated with ordnance usage.

Dipole size is an obvious feature to use to refine the target list. Unfortunately, the dipole fit size estimate for any given object will depend heavily on the orientation of the object in question. Figure 4 presents feasibility curves for a selection of ordnance items listed as possible items of interest at VTNR. These curves show how the dipole response for any given ordnance item can vary depending upon its physical orientation with respect to the Earth's field. The dipole response is non-unique for any shapes other than a sphere. The maximum moment is achieved when the target is aligned with the Earth's field and the minimum moment is achieved when the target is normal to the Earth's field (note the image in Figure 4 depicts the dipole angle, not the physical angle of the object). It is also apparent from this image that multiple ordnance types occupy the same spot on the graph, thus they may provide the identical responses. Furthermore, there are an infinite number of non-ordnance ferrous objects whose responses may also overlap with responses of the objects of interest. For this reason, total magnetic field techniques cannot be used to definitively declare an object as ordnance. However, to the extent that a given target response does not come close to the feasibility curves of the objects of interest these features can be used to exclude these targets from the refined target list.

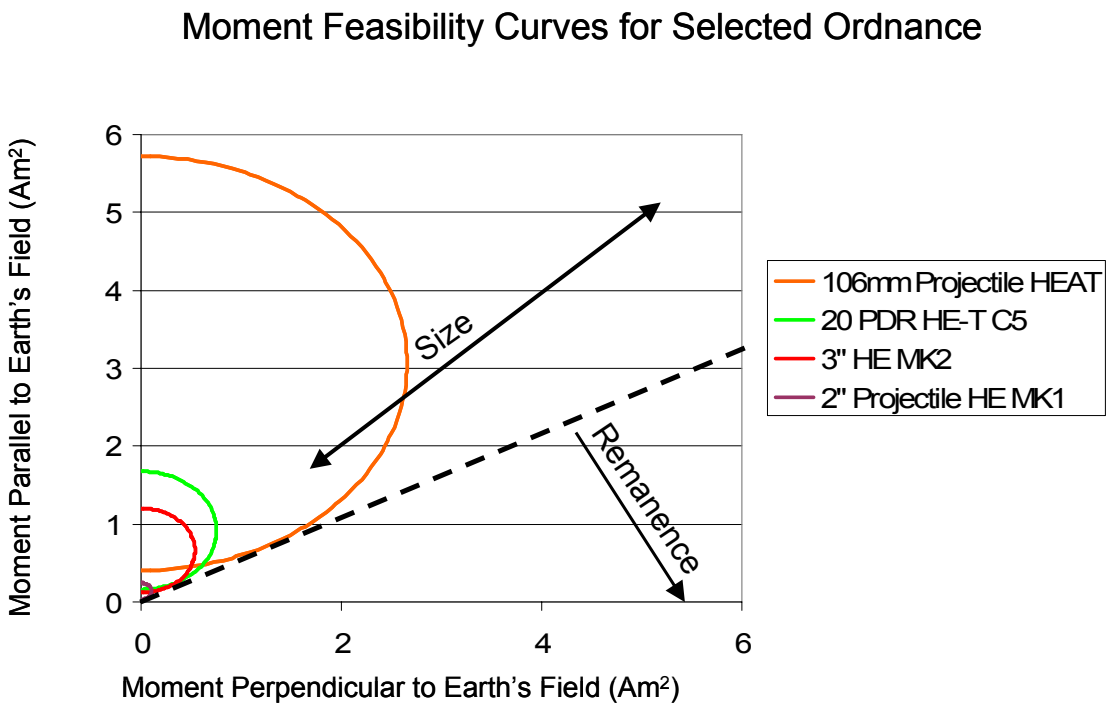

Figure 4. Dipole response feasibility curves. The predicted dipole moment for given ordnance types are plotted relative to the Earth's magnetic field vector. Dipole response angles greater than 60º indicate the presence of remanent magnetization. Note that the dipole angle, although related, is not the physical angle of the object.

3.6.4 Target Density Distribution Maps

Target density distribution maps are the final product of the HeliMag data processing. In order to aid in visualizing the distribution of metallic items across the site, a density raster will be computed using a 100 m radius neighborhood kernel that assigns anomaly densities in anomalies per hectare to each cell in the raster. The density maps will be annotated to contain the following information:

- Site name
- Map product
- Survey location
- Vertical scale bar
- Project coordinate system grid and labels

In addition to the target density maps, an ASCII listing of the selected targets will be provided. This list will include

- Site name
- Survey location
- Unique anomaly identification numbers
- Anomaly easting and northing in project coordinate system and/or local coordinates
- Selected QC anomalies
- Geophysical data value

3.7 Data Deliverables

3.7.1 Quality Control Data Sets

Fully analyzed data from each QC data set will be provided to the CH2M Hill project geophysicist via the ftp site no later than one working day after data collection each day. QC data set deliverables will include the following:

- Image file (such as a portable document format [pdf]) showing graphical results of each quality control test
- Geosoft ".xyz" file for each QC set; XYZ data sets must include columns for X, Y, raw data, final data, and any other applicable data
- Clear accompanying information to determine the contents of each file

3.7.2 Final Data Sets

Fully processed data from each survey and its associated QC data sets will be provided to the CH2M Hill project geophysicist via ftp site no later than 5 working days after collection of that particular data set is completed. Deliverable will include the following:

- Geosoft ".xyz" file for unit of survey being delivered (such as a grid or area agreed upon with CH2M Hill Munitions Response geophysicist); XYZ data sets must include columns for X, Y, raw data, final data, and any other applicable data
- Geosoft ".grd" file for unit of survey being delivered
- Geosoft ".gdb" file for unit of survey being delivered
- Geosoft ".map" file for unit of survey being delivered
- Geosoft map in pdf for unit of survey being delivered; all maps to include title, scale, north arrow, color scale, index map, legend, creator, and date created
- Geosoft map in pdf mosaic of all processed data to date; all maps to include titles, scale, north arrow, color scale, index map, legend, creator, and date created
- Clear accompanying information to determine the contents of each file

3.7.3 Project Documentation

SKY will document all field and data processing activities in the following reports:

Validation Lane Survey Log: This log documents the results from the Daily Validation Lane Flights and QC checks.

Data Acquisition Log: This log documents information about each survey event and summarizes crew, equipment, filenames, and surveyed areas. The following will be tracked:

- Date of data collection
- Sortie ID
- Site ID
- Survey line file (track file)
- Survey lines flown
- Name of pilot
- Name of system operator
- Name of ground support technician
- Name of data processor
- Name of project geophysicist
- Field notes (comments)

Data Processing Log: This log documents by sortie the data processing steps performed on each sortie as well as visual and statistical data quality checks. The tracking sheet will incorporate the sortie tracking information, as well as the processing steps and output as follows:

- Date of data collection
- Sortie ID
- Site ID
- Survey line file (track file)

- Survey lines flown
- Name of pilot
- Name of system operator
- Name of ground support technician
- Name of data processor
- Name of project geophysicist
- Field notes (comments)
- All filtering information (such as Demedian or L-pass)
- All QC check results (down-line sample density, spike rejection)
- Oasis site database
- Name of grid
- Name of archive

Data Analysis Report: This report, documents by site the various analysis steps as follows:

- Name of site
- Name of grid
- Name of archive
- All QC check results (altitude performance, survey coverage)
- Anomaly selection method (manual/wavelet/AS peak detection)
- Name of anomaly selection analyst
- Name of anomaly list file
- Name of anomaly QC analyst
- Name of anomaly list after final QC
- Name of analyst performing dipole fit/classification
- Name of dipole fit analysis output file
- Name of anomaly classification output file
- Dipole fit/Classification QC name
- Name of geographic information systems (GIS) analyst
- Name of GIS density map output file
- Density map QC name

3.7.4 FTP Site Requirement

All deliverables will be posted to a CH2M Hill-provided ftp site.

3.7.5 Aerial Magnetometer Survey Report

After completion of the field investigation and data analysis, an Aerial Magnetometer Survey Report will be prepared.

A general preliminary outline is as follows:

- Table of Contents
- List of Acronyms
- Introduction
  - Background and Project Objectives
  - Scope of Work
  - Site Location and Description
- Equipment
- Methodology
  - AMS Survey Activities
  - Data Processing and Interpretation
- Results
  - Summary of Work Performed
  - Mobilization and Site Setup
  - AMS Survey Activities
  - Data Processing and Interpretation
- Quality Control
  - System Validation
  - AMS Instruments and Positioning System Quality Control
- Conclusions
- References
- Attachments
  - Examples of data deliverables (such as maps and QC results for each type of QC test)
  - E-size mosaic plate(s) showing AMS results
  - E-size mosaic plate(s) showing anomaly selection locations
  - Photographs of AMS equipment and operations
  - Compact Disc (CD) (or digital video disc [DVD]) with all data and deliverables, including a document in pdf describing contents of folders

4.0 QUALITY CONTROL PLAN

4.1 Introduction

This Quality Control Plan (QCP) describes the QC approach and procedures for the AMS operations. The purpose of this QCP is to ensure that the AMS data collected is appropriate to meet the survey objectives. Challenges for airborne surveys include, intrinsic noise levels, data positioning, and navigation (horizontal and vertical). The DQOs provided in Tables 1 and 2 are designed to ensure that these challenges are met with the rigor required to ensure that the quality of the final data set is sufficient to support the observations and conclusions made in support of the survey objectives. In this QCP we describe the QC organization and responsibilities, initial IVS tests, and QC of production survey data acquisition.

4.2 QC Organization and Responsibilities

This subsection identifies QC responsibilities associated with key members of the QC organization and describes communication procedures that will be followed throughout AMS operations.

4.2.1 Key QC Personnel

The organizational structure and responsibilities of the SKY AMS team is designed to provide comprehensive QC for the project. Selected positions with primary QC responsibilities are described in the following paragraphs.

4.2.1.1 Sky Research Project Manager

The Project Manager is responsible for overall project activities, including cost control, schedule control, and technical quality. The project manager has ultimate responsibility within the project team for producing deliverables that are technically adequate, satisfactory to CH2M Hill, and cost effective. To accomplish this, the project manager develops an internal project review schedule, and monitors budgets and schedules. The project manager will work with the project team to select an internal QC review team, to coordinate review efforts, and to address review comments.

4.2.1.2 Sky Research AMS Geophysicist

The SKY AMS Geophysicist reports to the project manager and is responsible for coordinating overall field efforts. As the lead SKY field representative, he is also responsible for ensuring that field activities are performed in accordance with approved Work Plans, policies, and field procedures. The SKY AMS Geophysicist is responsible for implementing and administering field aspects of the project QCP and communicating the onsite QC program policies, objectives, and procedures to the project personnel during project meetings and informal discussions. The SKY AMS Geophysicist will be the direct contact for the CH2M Hill site manager.

4.2.1.3 Sky Research QC Geophysicist

The SKY QC geophysicist is responsible for reviewing AMS data, ensuring all QC tests have been performed and data pass DQOs and QC criteria, and deliverables are prepared as specified in project documents. The SKY QC geophysicist approves all data

deliverables for delivery to the CH2M Hill project/QC geophysicist, certifies that appropriate QC has been performed on the data prior to delivery and adjudicates all technical issues.

4.2.1.4 Pilot in Command

The PIC is responsible for flying the helicopter in a safe efficient manner. The PIC makes all final decisions that affect the safety of the aircraft and crew, including survey flight parameters (speed, altitude) and work stoppages due to weather conditions. Gaps in coverage due to terrain/obstacle avoidance are allowable at the PIC's judgment.

4.2.2 Project Communication

One of the most critical elements in performing any type of project is to establish and maintain lines of communication among all project personnel. At the beginning of the project, the Project Manager will prepare written project instructions that will be distributed to all team members. These instructions will document project and task instructions, and each team member's responsibility in achieving the objectives, as well as a budget and schedule for successfully executing the work.

Before field activity begins, a project team meeting will be conducted to review the concept, assumptions, objectives of the field approach, and project objectives. During the field investigation phase of the project, the field teams will meet daily to review the status of the project and to discuss technical and safety issues. When necessary, other meetings will be scheduled, or the site manager will meet individually with field personnel, to resolve problems.

During the field effort, the site manager will be in regular telephone or face-to-face contact with the project team. When significant problems or decisions requiring additional authority occur, the site manager can immediately contact the Project Manager for assistance.

All communications with the Navy will be channeled through the CH2M Hill Project Manager, who will be informed on a daily basis of field activities being conducted.

4.3 Instrument Validation Survey

Prior to commencement of data acquisition an IVS will be performed. The primary objective of the IVS will be to document the site-specific capabilities of the HeliMag system to operate as an integrated system capable of meeting project DQOs and to validate that the specific system to be used is functional and operating within industry standards. For the purposes of the IVS tests, a system is considered to include the survey platform, sensors, navigation equipment, data analysis and management, and associated equipment and personnel. The technologies to be tested are the component technologies listed previously, with the seven magnetometers configured at 1.5 m spacing. The IVS will be seeded by CH2M Hill with inert items or simulants. The HeliMag operations geophysical team will begin surveys of the IVS once mobilization is complete. The IVS will follow the SOPs provided in the AMSOP.

The survey altitude is a critical parameter for this type of investigation as the ability to detect objects of a given size is dependent upon the survey altitude above the object. Therefore, the objective for the HeliMag data collection is to maintain a safe altitude

while still supporting a significant level of detection. Under ideal topographic and vegetation conditions, survey data are collected at a nominal sensor altitude of 1.5 to 3 m AGL. However, the conditions at VNTR are less than ideal due to the presence of both rugged topography and significant vegetative cover. The detection capability of the HeliMag system at these altitudes, up to 10 m, will be evaluated using the results of the IVS. The IVS will be flown at multiple altitudes from the lowest the system can safely fly to approximately 10 m AGL at approximately 1 m increments for comparison and analysis purposes.

The IVS objectives will be attained through evaluation of the achievement of the DQOs (as provided in Table 1), observation of the IVS activities by the CH2M Hill Project Geophysicist and review of previous industry and CH2M Hill experience with the geophysical instruments considered.

Table 1. Proposed Data Quality Objectives for Instrument Validation Surveys at VTNR

Data Quality Objective	Measurement Performance Criteria	Evaluation Method During Production Survey
Accurate coordinates are being obtained from positioning systems.	Positional error of targets emplaced in a validation lane will not exceed ±50 cm.	Review of low altitude validation flight data analysis results for emplaced targets.
Repeatable data are being obtained from system.	Derived target size and dipole angle will be consistent to within 20% and 20° respectively.	Review of validation flight data analysis results.
Ordnance detection: survey system response is comparable to expected response of geophysical instrument.	Sensor response over specific items to be compared to response of geophysical instrument over similar items under previous test or field production conditions.	Verify that system response is comparable to response expected through previously documented instrument capabilities.
Down-line data density is sufficient to detect MEC items.	Over 98% of possible sensor readings are captured along a line spacing of no greater than 0.2 m between points. In addition, any flight lines containing a down line data gap of 2 m or greater does not meet the DQO.	Results of HeliMag surveys will be evaluated to ensure compliance.
Coverage over survey area is sufficient to detect MEC items.	Flight line gaps not to exceed 2.5 m over the emplaced anomalies..	Results of HeliMag surveys will be evaluated to ensure compliance.
Survey altitude is sufficient to meet goals of IVS.	Data are collected in separate passes at nominal 1m intervals from 2 – 10 m AGL.	Sufficient passes must be performed along this range of altitudes to allow prediction of maximum survey

Data Quality Objective	Measurement Performance Criteria	Evaluation Method During Production Survey
		altitude for reliable detection of 155-mm projectiles in the VNTR environment.
Intrinsic noise	Below 1 nT.	Results of data collected at high altitude out of ground effect will be evaluated to ensure compliance.
Data Handling		
All data must be delivered in a timely manner and in a useable format.	Quality Control Data Sets are completed and delivered to the CH2M Hill Project Geophysicist within 1 working day of data collection and Final Data Sets within *5* working days of data collection.	Evaluate based on actual delivery of data.

4.4 Production Survey Data Quality Objectives

During the survey data acquisition phase of this project, system functionality, survey acquisition parameters, and data delivery time objectives will be monitored. The DQOs for this phase of the project are provided in Table 2 below. A more detailed discussion of the DQOs is provided below.

Table 2. Proposed Data Quality Objectives for Aerial Magnetometry Survey at VTNR

Data Quality Objective	Measurement Performance Criteria	Evaluation Method During Production Survey
General System Functionality		
Accurate coordinates are being obtained from positioning systems.	Positional error of targets emplaced in a validation lane (flown twice daily) will not exceed ±50 cm.	Daily review of validation flight data analysis results.
Repeatable data are being obtained from system.	Derived target size and dipole angle will be consistent to within 20% and 20° respectively (for validation line data collected daily)	Daily review of validation flight data analysis results.
Ordnance detection: survey system response is comparable to expected response of geophysical instrument.	Sensor response over specific items to be compared to response of geophysical instrument over similar items under previous test or field	Verify that system response is comparable to response expected through previously documented instrument capabilities.

Data Quality Objective	Measurement Performance Criteria	Evaluation Method During Production Survey
	production conditions.	
Survey Data Acquisition		
Down-line data density is sufficient to detect MEC items.	Over 98% of possible sensor readings are captured along a line spacing of no greater than 0.2 m between points. In addition, any flight lines containing a down line data gap of 2 m or greater does not meet the DQO.	Results of HeliMag surveys will be evaluated to ensure compliance. Gaps due to obstacle/terrain avoidance consistent with the safety of aircraft and crew are acceptable and will not be cause for re-flights.
Coverage over survey area is sufficient to detect MEC items.	Flight line gaps not to exceed 2.5 m for distances > 500 m.	Results of HeliMag surveys will be evaluated to ensure compliance. Gaps due to obstacle/terrain avoidance consistent with the safety of aircraft and crew are acceptable and will not be cause for re-flights.
Survey altitude is sufficient to meet declared detection goals	80% of the sensor readings will be collected within 2 m of (or below) the predicted survey altitude AGL.	The predicted survey altitude will be imported into the data base and subtracted from the survey altitude. Note discussion points in accompanying text.
Intrinsic noise	Below 1 nT	Results of data collected at high altitude out of ground effect will be evaluated to ensure compliance.
Data Handling		
All data must be delivered in a timely manner and in a useable format.	Quality Control Data Sets are completed and delivered to the CH2M Hill Project Geophysicist within 1 working day of data collection and Final Data Sets within *5* working days of data collection.	Evaluate based on actual delivery of data.

HeliMag data are positioned to better than 0.1 m. However, verification of this level of accuracy for a dynamic system is difficult. For this reason we verify position accuracy though the use of seeded targets. The measurement performance criterion for this is that the positional error at known monuments emplaced in a validation lane (flown twice daily) will not exceed ±50 cm. This will be evaluated by ensuring that dipole fit analyses results for emplaced targets meet this criterion.

The DQO for HeliMag systems data repeatability is that the systems respond consistently from the beginning to the end of an operation. As with the positioning accuracy DQO, determining repeatability with a dynamic system where the target/sensor separation distance varies from pass to pass is very difficult. However we can use the consistency of the emplaced target dipole fit results to indicate that the system performance is stable. The measurement performance criterion for this is that the derived target size and dipole angle will be consistent to within 20% and 20° respectively (for validation line data collected daily).

The DQO for inert ordnance items detection is to detect items comparably to what would be expected through either documented instrument tests or instrument response models for the instrument being validated. The focus of the analysis for detection is concentrated on determining that the geophysical instrument and the system as a whole is functioning as designed and to evaluate the background noise (created by the geology or outside electromagnetic influences) at the particular location.

The DQO for down-line (along the survey transect) data density is to have sufficient data collected along each transect to detect targets. The measurement performance criterion for this is that at least 98 percent of possible sensor readings are captured along each transect at 0.5 m or less. In addition, any transect (or portion thereof) containing a data gap of 2 m or greater does not meet the DQO. Results of HeliMag surveys will be evaluated to ensure compliance. Gaps due to obstacle/terrain/vegetation avoidance consistent with the safety of aircraft and crew are acceptable and will not be cause for re-flights.

The DQO for lane spacing is to maintain appropriate lane spacing to provide 100 percent coverage of the survey area. The measurement performance criterion for this is that the lane spacing variation results in gaps no greater than 2.5 m for distances greater than 500 m. Results of the HeliMag surveys will be evaluated to ensure compliance. Gaps due to obstacle/terrain /vegetation avoidance consistent with the safety of aircraft and crew are acceptable and will not be cause for re-flights.

Survey altitude is the prime determinant of signal strength. Thus, provided the intrinsic system noise is below a reasonable level, survey altitude is a prime determinant of detection performance. Both the terrain and vegetation at VNTR militate against maintaining consistent survey altitudes below the standard operating altitude of 3 m AGL or lower. Safety of the aircraft and crew is paramount, and the decisions of the PIC with respect to survey altitude and terrain/obstacle avoidance are final. Consequently, derivation of a meaningful, enforceable DQO for survey altitude is somewhat complicated. Although, ideally all survey data would be collected below 3 m AGL, this is obviously not possible, thus it would not be enforceable. Conversely using a very high altitude as the DQO would not have much meaning, nor does it meet our stated QC objectives. In response, SKY is proposing that we base the DQO on the original terrain/vegetation analysis that was presented in our proposal. This model analysis is the best prediction of our expected altitude performance available.

The DQO for intrinsic noise is not more than 1 nT. The intrinsic noise value is considered accumulated noise from sensors and sensor platforms, including GPS, rotor noise, radio frequencies, etc., calculated as the standard deviation of a 20 second window of

processed data collected out of ground effect. Results of the HeliMag surveys will be evaluated to ensure compliance.

The DQO for data handling is that all data must be delivered in a timely manner and in a useable format; the QC data sets must be completed and delivered to the CH2M Hill Project Geophysicist within 1 working day of data collection and final Data Sets within 5 working days of data collection.

4.5 Definable Features of Work

The definable features of work (DFOW) specific to the AMS operations are summarized in Table 3.

Table 3. Definable Features of Work, Auditable Functions, and Responsibilities – Aerial Magnetometer Surveys

Definable Feature of Work with Auditable Function	Responsible Person(s)[a]	Audit Procedure	Freq. of Audit	Pass/Fail Criteria	Action if Failure Occurs
IVS Execution	Sky QC Geophysicist	Verify DQOs established in IVS Work Plan have been accomplished.	O	DQOs identified in IVS Work Plan have been achieved	Continue with IVS until DQOs are achieved.
AMS Survey	Sky Geophysicist	Verify AMS Survey conducted IAW AMSOP.	O/D	Data collection conducted IAW Wide Area Assessment Investigation Plan	Stop activity until full compliance ca be assured and any activities not performed within compliance are re-evaluated and re-performed if necess
AMS Survey	Sky QC Geophysicist	Check results of QC tests performed as specified in AMSOP.	E	QC tests must pass IAW standards determined during the IVS and referenced SOPs.	If a QC test does not pass, a root-cau analysis must be performed, and the project team must meet to discuss an determine appropriate action.
AMS Survey	Sky QC Geophysicist	Confirm that data collection DQOs established during IVS are being achieved.	E	Data collection DQOs are being achieved.	If the DQOs are not being achieved, root-cause analysis must be performe and the project team must meet to discuss and determine appropriate action.
AMS Data Processing	Sky Geophysicist	Verify data checks specified in AMSOP.	E	Data checks must pass in accordance with standards determined during the IVS and referenced SOPs.	If a QC test does not pass, a root-cau analysis must be performed and the project team must meet to discuss an determine appropriate action.

IAW = in accordance with Frequency: O = Once D = Daily E = Each occurrence

[a] The responsible person is the individual with whom the CH2M Hill QC Geophysicist will coordinate to ensure compliance with requirements and to verify that any necessary follow-up actions are taken.

5.0 HEALTH AND SAFETY PLAN

5.1 Introduction

This HASP establishes general and site-specific health and safety requirements specific to the Sky Research portion of the CH2M Hill Former Vieques Naval Training Range, Expanded Range Assessment and Phase II Site Inspection being conducted under the NAVFAC CLEAN 1000 Program CTO 23 at Vieques, Puerto Rico.

SKY will be performing low altitude airborne magnetic surveys at the site. This HASP will address general aviation safety measures, guidelines for conducting survey operations, potential hazards associated with aircraft operations and ground support, and emergency response procedures. As in all airborne operations, final decisions regarding safety of the aircraft, crew and passengers are the responsibility of the aircraft operator and the pilot in command. In addition, compliance with the Federal Aviation Administration (FAA) regulations and standards for civilian aircraft operations, and FAA approved aircraft specific maintenance procedures and flight manuals are mandatory.

Because not every health and safety hazard encountered in the field can be anticipated, field personnel must be equipped and trained to recognize and respond to unforeseen hazards. Above all, employees must maintain a high level of safety awareness and exercise common sense and good judgment when confronted with a hazardous or unsafe situation.

All personnel and visitors involved with SKY activities at the site are expected to read and abide by all provisions of this HASP. All personnel participating in on-site activities will sign a document stating that they have read, understand, and will abide with the requirements of the HASP. This HASP provides guidelines to protect personnel, the public, property, and the environment from hazards associated with site activities and potential site contaminants.

5.2 Aircraft Operations

The following are general guidelines for performing airborne survey operations.

5.2.1 Aircraft Ground Support Operations

- Daily inspections and preflight inspections of aircraft and equipment installations will be performed pursuant to manufacturer's specifications.
- Flight plans are to be filed as appropriate. Where flight plans are required by local authorities, a company flight plan will be made and monitored.
- Preflight briefings are to be performed prior to each survey flight. Ground crew must be aware of planned flight activities, fuel reserves, and estimated return times.
- Weight and balance calculations must be performed after any modification to the aircraft, including initial installation of any survey equipment.
- Daily weather forecasts are to be obtained prior to commencement of survey operations.
- Site-specific hazards will be addressed prior to commencement of survey operations.

- Ground support personnel will wear proper Personal Protective Equipment (PPE).
- During landing and takeoff maneuvers, ground personnel will remain well clear of the aircraft.
- Never approach or leave the aircraft without the pilot's knowledge – always approach and leave the aircraft within sight of the pilot.
- Fueling is to be performed by qualified personnel only. Non-qualified personnel must stay clear of the aircraft during fueling operations.
- The aircraft must be grounded prior to fueling operations.
- Fueling personnel will have absorbent diapers available for spill cleanup.

5.2.2 Airborne Operations

- The PIC has complete jurisdiction over all aircraft related operations, emergency response activities and requirements.
- No aircrew member will fly while under the influence of substances, including alcohol and illegal, prescription, or over the counter drugs, which may impair physical or mental acuity.
- The aircraft operator shall maintain up to date insurance.
- Only necessary personnel are permitted on board during flight operations.
- The PIC has the authority to abort any flight for safety considerations.
- The PIC may deviate from survey specifications (speed, altitude and/or flight duration) for safety considerations.
- Over-flight of restricted areas may only be performed with authorization from the appropriate authorities.
- The pilot is in 2-way radio communication with ground personnel (if necessary or required).

5.3 Emergency Response Procedures (Airborne Operations)

These site-specific emergency response procedures are intended to provide a preplanned course of action to cover aircraft-related emergencies during survey operations. A list of contact numbers and pertinent information will be maintained at the base of operations. All actions will be initiated by the Project Manager on-site. Conditions resulting in the invocation of these procedures are defined as Alert Levels I, II, or III. Definitions of each Alert Level and appropriate responses are provided as follows:

Level I - Overdue Aircraft:

Initiated by:

- A missed scheduled radio report or estimated time of arrival (ETA) by ten minutes.

Objective:

- To ascertain if delays in reporting or arrival are due to communication difficulties, or diversion of aircraft due to weather or in-flight problems.

Action:

- Request a communication search from local air traffic control (ATC) authorities.
- Prepare for a ground search (where feasible).
- Take appropriate action, including progression to Alert Level II.

- Begin log of actions and timelines.

Level II – Missing Aircraft:

Initiated by:
- Missed scheduled radio report by 30 minutes.
- Missed ETA by 20 minutes.
- Receipt of radio report of problems in flight.
- Failure to return after fuel supply including reserves is exhausted.

Objective:
- Ascertain if the aircraft has landed at an alternate location.

Action:
- Advise ATC and request action plan to be initiated.
- Call local Search and Rescue (SAR) or emergency response teams and advise of overdue aircraft.
- Perform ground search of alternate landing sites.
- Take appropriate action, including progression to Alert Level III.
- Update log of actions and timelines.

Level III – Missing Aircraft Presumed to Have Crashed:

Initiated by:
- Receipt of a MAYDAY, SOS, or ELT signal from the aircraft, or ground.
- Report of a distressed or downed aircraft.
- Missed ETA by 30 minutes and failure to make radio or visual contact at alternate landing sites.

Objectives:
- Locate downed aircraft as quickly as possible, ascertain medical requirements, and dispatch immediate medical help.

Action:
- Provide location information (including last known position, and planned flight activities) as well as all pertinent flight plan information (helicopter type, registration, number of passengers) to SAR personnel.
- When aircraft is located, note time, specific location, condition of crew and conditions around crash site including nearest landing zone and ground access routes.
- Advise and update appropriate emergency personnel (local police, ambulance, fire department, ATC). Transfer command to trained SAR personnel (civil or military) at earliest possible time without compromising the above-mentioned objectives.
- Continue detailed log of actions and timelines.

5.4 Ground Support Operations

5.4.1 Ground Support Field Tasks

Ground support field operations are summarized as follows:
- Pre-flight site visits

- Field oversight activities, including coordinating and managing site preparation operations
- Emplacement of ground survey targets and fiducials
- GPS base station operation
- Field calibrations (record basic site information, photos, RTK GPS coordinates, feature measurements)
- Provide first aid kits and fire extinguishers for use at the field work sites and vehicles
- Provide basic first aid to injuries until emergency response personnel arrive

The sections below evaluate information on UXO hazards likely to be encountered, as well as physical and biological hazards at the site. The potential of these hazards to affect the field activities is also discussed.

5.4.2 Unexploded Ordnance

Many of the airborne investigation survey areas have not been surface cleared of UXO. UXO avoidance procedures will be followed at all times on-site while providing ground support.

5.4.3 Motor Vehicles

All SKY personnel operating company owned, leased or rented motor vehicles on site will hold a valid drivers license and comply with local, state and federal traffic regulations. Personnel will perform vehicle safety inspections daily. All personnel will drive defensively and wear seat belts while vehicles are in motion.

5.4.4 Physical Hazards

Personnel may be exposed to physical hazards, such as severe heat stress; excessive noise levels; and slip, trip, and fall hazards. Engineering controls will be used whenever possible to control physical hazards. Personnel will also use appropriate PPE to minimize exposure to these hazards.

In the event of severe weather, site activities will cease until the field team leader has determined that it is safe to resume operations. Severe weather will include any type of climatic anomaly that presents additional, uncontrollable risk to personnel health and safety.

To prevent heat or cold stress problems, the field team leader will closely monitor personnel working in extremely hot, wet, or cold weather. If conditions become extreme, personnel will be given breaks to reduce the likelihood of heat or cold stress.

Excessive noise levels may be generated from field equipment, aircraft, and other heavy equipment. The field team leader will qualitatively monitor noise levels and will require site personnel to wear hearing protection whenever noise levels are perceived to be dangerous.

Noise control measures will include the following:

- Providing protection against noise exposure for all site personnel when necessary. Action levels will be based on the US Army Corps of Engineers

(USACE) Safety and Health Requirements Manual (EM 385-1-1), Section 23, Noise Control, and regulatory requirements established by the Occupational Safety and Health Administration (OSHA).

- Using feasible engineering or administrative controls, whenever noise levels exceed specified limits. According to OSHA regulations, the action level for 8-hour exposures is 85 decibels on the A scale (dBA), measured using the slow response mode. According to the USACE Safety and Health Requirements Manual, permissible noise exposure for 8 hours is 90 dBA. For this project, the 85 dBA limit will be used.

Other physical hazards associated with the site may include the following:

- Uneven terrain and heavily vegetated areas
- Sun exposure
- Vehicle traffic

5.4.5 Biological Hazards

Biological hazards include animal bites or stings that may cause localized swelling, itching, and minor pain and can be handled by basic first aid treatment. The bites of certain snakes, lizards, and spiders may contain sufficient poison to warrant medical attention. In addition, ticks can spread Rocky Mountain spotted fever and Lyme disease; dogs, skunks, foxes, and other small mammals can spread rabies; and mosquitoes can spread West Nile and encephalitis viruses.

Bee and wasp stings, spider bites, and other insect bites may cause allergic reactions. Anaphylactic shock from stings can lead to severe reactions in the circulatory, respiratory, and central nervous systems of an allergic person and can cause death in severe cases. Personnel assigned to this project who are allergic to insects will be required to carry their prescribed treatment and will notify the field team leader of the nature of any allergies or health problems, as well as the location of medications. All stings or bites will be taken seriously. Personnel stung or bitten will be required to stop work and will be observed for signs of severe swelling, shortness of breath, nausea, or shock. Medical attention will be obtained immediately if any of these symptoms appear. To prevent exposure to insect bites, site personnel will use insect repellents as appropriate. A first aid kit available on site will contain the necessary supplies to treat bites, stings, and other minor injuries. All on-site personnel will be knowledgeable in standard first aid procedures.

5.5 Site Control

Tasks associated with the site activities involve work in areas where hazardous substances or UXO could be present. However, if unexpected hazards are encountered in work areas, the field team leader will contact the appropriate authorities. If appropriate, barrier tape or traffic cones will designate the hazard zone. Access to a contaminated exclusion zone will be restricted to authorized personnel.

The field team leader will identify routes and areas that personnel are authorized to enter. The following sections discuss site access communications, the buddy system, safe work practices, and HASP enforcement as site control measures.

5.5.1 Site Access

Because most areas visited during this project are not active military installations, CH2M Hill personnel will control site access.

5.5.2 Communications

Successful communication between field teams and among field personnel is essential. The following communication systems, when appropriate, will be used during field activities:

- Cellular telephones
- Hand signals
- Field Radios

Field Radios or Cellular telephones will be used to communicate with parties outside of voice contact range and for emergency situations.

Hand signals may be used to supplement voice communication. The following standard hand signals will be used in case of radio communications failure or for emergency onsite communication:

- Both hands on waist — Return to support zone immediately
- Hands on top of head — Need assistance
- Thumbs down — Negative; no
- Thumbs up — Positive; yes; I'm all right
- Fist raised above head-level — Stop

A list of emergency and installation telephone numbers for each site is provided in Table 4 (Section 5.15.2). This list will be kept, with a map of the medical evacuation route(s), in all vehicles during site activities.

5.5.3 Buddy System

Personnel will use the buddy system during all on-site activities. The buddy system requires that two people work as a team, each looking out for the other. Buddies must maintain continuous line-of-sight contact with one another and be in a position to physically assist each other if assistance is necessary. Personnel will not be allowed to enter the site alone; a buddy must accompany each person. In emergency situations, personnel will evacuate the site using predetermined egress routes.

5.6 Safe Work Practices

Experience indicates that individuals working at UXO-contaminated sites are tempted to collect souvenirs while on site. Souvenir hunting while on the site is expressly prohibited.

Anyone observed picking foreign objects off the ground will be immediately expelled from the site. Even ordnance that is marked as inert may contain explosive charges in the fuses, unburned propellant, or other hazards.

Other general safe work practices for site operations include the following:

- All site operations will be discontinued immediately if an unforeseen hazardous condition develops.
- Only personnel and equipment needed to perform the required tasks will be permitted on the site.
- Matches, lighters, and other spark- or flame-producing devices are prohibited on the sites.
- Site operations will cease immediately upon the approach of an electrical storm or other severe weather conditions.
- If a fire occurs that may involve explosive materials, all personnel will immediately evacuate to the previously designated safe area using predetermined routes.
- Consumption of alcoholic beverages onsite is prohibited. Personnel having consumed alcoholic beverages during lunch or other breaks will not be allowed on-site.
- Effects of extreme climate conditions should be closely monitored during hot periods and all personnel should be aware of the symptoms and effects of heat stress, heat exhaustion, and heat stroke.

Workers will be aware of any potential trip and fall hazards. Whenever possible, trip and fall hazards will be eliminated or clearly identified with yellow caution tape. Site activities will proceed with caution in any area where the presence of utility lines (such as gas, telephone, and other lines) is known or suspected.

5.7 Emergency Contingency Planning

The field team leader and site manager will be notified of any onsite emergencies, and will be responsible for ensuring that appropriate emergency procedures are followed. A list of emergency telephone numbers and directions to the nearest hospital will be available on-site. Hospital route maps will be kept in all site vehicles. These emergency procedures will be coordinated with the installation's emergency response procedures before site work begins. PPE, emergency chain of command, evacuation procedures, emergency equipment, and emergency procedures are described in the following sections.

5.8 Personal Protective Equipment

Site personnel will wear long pants, ankle-high boots, safety glasses and gloves. If heavy machinery is in use, hard hats must be worn. If hardhats are to be worn in UXO areas, then they will be firmly attached to the head of the wearer.

Other PPE at the site will be discussed during the introductory safety, health, and emergency response briefing. The field team leader will also discuss site- and weather-specific PPE for the site activities as needed.

If unexpected hazardous substances or respiratory hazards are encountered, operations will cease.

5.9 Emergency Chain of Command

A clear chain of command in emergency situations will ensure clear and consistent communications among site personnel and will result in a more effective emergency response. The field team leader will direct SKY emergency response operations and

designate duties to other site personnel. The field team leader will make initial contact with off-site emergency response teams (such as first aid, fire, or police); stop work if necessary; and provide for on-site first aid and rescue. SKY personnel will escort the off-site medical team to the emergency site.

5.10 Evacuation Procedures

If required, personnel will evacuate work sites along access paths designated before the field activities begin. In most cases, this access path will be the most direct path to a designated safe area such as a road or site trailer. During evacuation, equipment will be placed so as not to impede emergency escape and evacuation along cleared paths.

5.11 Emergency Equipment

At a minimum, the following emergency equipment will be present in each vehicle and on site:

- First aid kit
- Multipurpose fire extinguisher
- Cellular telephone
- Field Radio

5.12 Emergency Procedures

Procedures for specific types of emergencies are outlined in the following sections; these emergencies include explosion and fires, chemical spills, and injuries or medical emergencies.

5.12.1 Explosion and Fires

In the event of an unplanned explosion or fire, personnel in the area of the explosion or fire should check to ensure that no personnel were harmed. In the case of such an event, personnel should evacuate the site along designated access paths. Personnel evacuating the site should notify the site manager using cell phones or radio as soon as practical, preferably while evacuating the site.

If personnel are injured, other personnel in the area should assess the situation and notify the site manager by cell phone or radio. If imminent danger does not appear to be a risk, all personnel should stay with injured parties and render first aid support. Otherwise, the injured party should be evacuated from the area along the designated access paths, unless moving the injured party would complicate the injury drastically. SKY personnel will notify the appropriate volunteer fire department or emergency response team.

If personnel are injured, the onsite personnel will escort the volunteer fire department or emergency response team across the site using the shortest linear distance to the injured party from the access road. While the volunteer fire department or emergency response team is assisting the injured party, other personnel will be escorted off the site.

The field team leader will witness the evacuation procedures and conduct a head count of all personnel. The team leader will then notify the volunteer fire department and emergency response team and will act as the onsite incident commander until the volunteer fire department or emergency response team arrives to assume incident

command duties. When the volunteer fire department or emergency response team arrives on site, onsite personnel will advise the responding crew chief of the location, nature, and identification of the explosion or fire.

Site personnel should perform the following procedures if they do not endanger personnel or equipment:

- Use an onsite fire extinguisher to control or extinguish any small, localized fires
- Remove or isolate flammable or other hazardous materials that may contribute to fires
- Designate personnel to direct the volunteer fire department or emergency response team
- Warn all occupants of any burning buildings to immediately evacuate
- Close windows, skylights, and doors to any burning buildings but do not lock

5.12.2 Injuries, Fire, or Medical Emergencies

In the event of an injury, fire, or medical emergency, qualified personnel should provide first aid, if required, and should contact the local volunteer fire department or emergency response team for assistance by dialing 911 on the telephone. In general, injured persons should not be moved except by medical emergency response personnel. However, *if* it is clearly safe to do so and will prevent no further injury, on-site personnel may transport injured persons to the nearest hospital.

UXO-related injuries may include traumatic amputation, bleeding, burns, concussion, shock, and death. If personnel are injured as a result of any emergency, UXO-related or otherwise, those personnel should be treated in accordance with emergency first-aid procedures until qualified medical help arrives on site.

If a chemical brought on site by a contractor causes the injury, personnel should use the first aid procedures outlined in the material safety data sheet for the chemical. Other chemical injuries are not anticipated.

5.13 Environmental Monitoring

The field team leader will observe personnel for signs of temperature stress and will monitor meteorological conditions during all field activities to ensure the safety and health of personnel as well as site visitors.

5.13.1 Temperature and Stress Protection Program

Heat and cold stress are serious conditions commonly encountered during fieldwork. The likelihood of a temperature-related illness depends on factors such as level of physical activity, clothing, wind, humidity, working and living conditions, and an individual's age and state of health. Although OSHA does not have regulations to limit temperature exposures, personnel working on this project will follow guidelines from the American Red Cross and the American Conference of Governmental Industrial Hygienists. This section discusses heat and cold stress and presents temperature stress guidelines.

Temperature stress will be reduced by using engineering controls, safe work practices, and management techniques. Field personnel will have been trained to recognize and respond to temperature-related illnesses as part of OSHA refresher training,

cardiopulmonary resuscitation training and first aid training. Field workers should monitor themselves and coworkers for signs of temperature-related illnesses. The field team leader is responsible for initiating rest schedules during fieldwork.

5.13.1.1 Heat Stress

The possibility of a heat-related injury during fieldwork is significant because some types of PPE increase the body's workload and decrease the body's means of cooling. Heat stress symptoms include heat cramps, heat exhaustion, and heat stroke. Heat stroke is the most serious condition and can be life-threatening. Control actions and rest schedules that may be used to prevent heat stress are provided below.

Depending on the degree and nature of possible heat stress, the field team leader will choose from the following heat stress control actions:

- Provide adequate liquids to replace lost body fluids. These liquids may be water, powdered commercial rehydrating mixes combined with water, or rehydrating commercial liquids (such as Gatorade®).
- Establish a work regimen that will provide adequate rest periods for cooling down. This action may require additional work shifts or earlier or later work schedules to avoid midday heat.
- Provide cooling devices, such as vortex tubes or cooling vests, to be worn beneath protective garments
- Require the removal of impermeable protective garments during rest periods
- Ensure that all rest periods are taken in a shaded rest area, if possible
- Regulate rest periods and ensure that workers will not be assigned other tasks during rest periods
- Notify all workers of health hazards and the importance of adequate rest, acclimatization, and proper diet
- Instruct workers how to recognize heat stress and to conduct first aid to prevent heat stress

SKY will use physiological monitoring to evaluate each individual's response to heat stress when ambient temperatures exceed 70° Fahrenheit (F) and impermeable garments are worn. Two physiological parameters that may be monitored by the field team leader are Heart Rate and Body Temperature. If the heart rate of any individual exceeds 100 beats per minute at the beginning of any rest period then the work cycle will be decreased by one-third. If the body temperature exceeds 99.6° F at the beginning of any rest period, then the work cycle will be decreased by one-third. The rest period will remain the same.

Higher heat exposures than those shown above are permissible if workers have been undergoing on-site medical surveillance and if it has been established that they are more tolerant of hot weather work than average workers. Workers should not be permitted to continue work when deep body temperatures exceed 100.4° F as determined through on-site medical surveillance.

All persons working at the installation should be acclimatized to local ambient temperature extremes before conducting heavy work. Personnel will be required to slow their work pace as ambient temperatures rise. Field personnel should increase their salt intake at meals to help prevent heat-related injuries.

Solar heat load and glare from sunlight are also major concerns. Adequate skin covering will be required and may include long-sleeved shirts, trousers, hats, sunglasses, and sun block on exposed skin surfaces. Clothing must be light and loose to allow for air circulation and cooling.

Personnel should memorize and learn to recognize the following heat-related injuries:

- Heat cramps. Primary symptom is cramping of muscles. Victims should rest in the shade and rehydrate until the symptom passes. Victims may wish to ingest salt to help the symptom pass.
- Heat exhaustion. Symptoms include normal to slightly high body temperature, increased sweating, pale skin, dizziness, and fast pulse. Victims should rest in the shade and rehydrate until symptoms pass, then perform only light duty activities for the remainder of the work day.
- Heat stroke. Symptoms include high to extremely high body temperature and hot, red, and usually dry skin. Without immediate medical attention, victims may lapse into a coma and possibly die. Medical attention should be sought immediately. Unaffected site personnel should immediately cool victims by any means available. Victims should be moved quickly to any nearby air-conditioned area. Victim's clothing should be soaked in water. The victim should be fanned with a towel or other object to provide air movement.

5.13.1.2 Cold Stress

Examples of cold-related injuries include frostbite and hypothermia. Susceptibility to these injuries increases with increasing wind speed, wet conditions, and lack of insulated clothing. This section provides control actions and guidelines for cold working conditions.

Cold stress may be of particular concern when a wind-chill adjusted temperature of 10° F or less is expected. Personnel working outdoors in temperatures at or below freezing may be frostbitten. Working in extreme cold even for a short time may cause severe injury to the body surface or may result in profound generalized cooling, causing hypothermia and possibly death. Areas of the body that have a high surface area-to-volume ratio, such as ears, fingers, and toes, are most susceptible to frostbite.

Ambient temperatures and wind velocity influence the development of a cold injury. Wind chill (the chilling effect of moving air) should be taken into consideration along with the air temperature when determining whether or not outdoors work is safe.

When chemical-resistant equipment is removed and the clothing underneath is soaked with perspiration, the body cools very rapidly. Workers should therefore avoid removing equipment until they are in a warm area. Thermal socks, long cotton or thermal underwear, hard-hat liners, and other cold-weather gear can help prevent hypothermia. Blankets, warm drinks (other than caffeinated coffee), and warm rest areas are essential to preventing cold-related injury.

Local body injury from exposure to cold is included in the generic term “frostbite.” Frostbite symptoms can be categorized according to the following degrees of severity:

- Frostnip or initial frostbite is characterized by sudden blanching or whitening of

the skin.

- Superficial frostbite causes the skin to have a waxy appearance and to be firm to the touch while the tissue underneath is resilient.
- Deep frostbite causes the skin to be cold, pale, and solid. This degree of frostbite is extremely serious.
- Systemic hypothermia manifests itself in five stages of symptoms, including: (1) shivering; (2) apathy, listlessness, sleepiness, and sometimes rapid cooling of the body to less than 95° F; (3) unconsciousness, glassy eyes, and slow respiration and pulse; (4) freezing of the extremities; and (5) death.
- Trench foot or immersion foot occurs when feet are kept cold and/or wet for an extended period of time. Feet become pale, cold, and possibly pulse less during recovery, feet become red, hot, and swollen from excessive blood flow. Trench foot is generally contracted in freezing temperatures (32° F or less), while immersion foot is contracted at non-freezing temps, generally below 50° F.

5.13.1.3 Meteorological Monitoring

The field team leader will note the wind direction, general weather conditions, and temperature each day. In addition, weather conditions will be monitored at the site trailer and important information will be relayed via two-way radios.

Field operations during summer can create a variety of hazards. Heat cramps, heat exhaustion, and heat stroke, if not remedied, can threaten health or life. Fieldwork during the winter can also cause health hazards, including hypothermia and frostbite. Therefore, as part of the initial site safety, health, and emergency briefing, personnel will be reminded of the symptoms of these conditions and the appropriate remedial actions. In addition, meteorological conditions of concern include thunderstorms, hail, high winds, heavy rains, and the possibility of tornadoes.

5.14 Accident Prevention Plan and Reporting

Personnel should immediately report all accidents or incidents to the field team leader. The field team leader will immediately ensure that necessary first aid and corrective actions have begun and, if necessary, that emergency agencies have been called. The field team leader will notify the site manager (if applicable) about the accident.

5.15 Site Specific Information

5.15.1 Base Operations

The helicopter will base out of Antonio Rivera Rodriguez Airport, Isla de Vieques, Puerto Rico (TJVQ). Normal ATC communications will be used during the taxi / takeoff and climb out phase of the data collection flights on the island. The pilots will be in contact with ATC and receive VFR traffic advisories during the flights. Daily operations will be based out of Camp Garcia in Central Vieques, utilizing the Ch2M Hill trailer and support facilities

5.15.2 Local Emergency Information

All health care facilities and pharmacies are located in the downtown area of Vieques. Farmacia (pharmacy) San Antonio can be found on Calle Benitez Guzman across from

the Tourism Office; and Isla Nena Pharmacy is located on the main street across from the bank. The local clinic, CDT Susana Centano is on road 997 close to the entrance to Isabel II. The clinic has a 24-hour emergency and labor and delivery service. The Police Station is in downtown, 787 741-2020 or 787 741-2121, next to the Middle School. If there is an emergency of any type one should dial 911. Local emergency services contact information is provided in Table 4.

Table 4. Emergency Contact Numbers for Vieques Island, Puerto Rico

Emergency Service	Emergency No.	Non-emergency No.	Location
Police	911	787 741-2020 or 787 343-2020	Downtown
Ambulance	911		
Fire	911	787 741 2111 or 787 343-2330	
Susana Centano Hospital	911	787 741 3282	South of Isabel Segunda on Road 997
FAA		787 253 8664	San Juan
Coast Guard		787 289 2041	San Juan
Isla Nena Pharmacy		787 741 1906	Main Street
Farmacia San Antonio		787 741 8397	Calle Benitez Guzman

5.15.3 Guidelines for Off-Shore Flights

Because of the island location, the SKY MD530F Helicopter and crew may be required to fly over open waters. The highest risk level related to the operations is Medium-Catastrophic/Improbable, associated with the emergency ditching scenario (Table 5).

Table 5. Risk Matrix, AR 385-16, MIL-STD-882C, ATTC MEMO 70-12

HAZARD SEVERITY		HAZARD PROBABILITY				
		FREQUENT Likely to Occur Frequently During The Test	PROBABLE Will Occur Several Times During the Test	OCCASIONAL Likely to Occur Sometime During the Test	REMOTE Unlikely but Possible to Occur During the Test	IMPROBABLE So Unlikely It Is Assumed Occurrence May Not Be Experienced
		A	B	C	D	E
CATASTRO-PHIC Death or System Loss	I	High	High	High	High	Medium
CRITICAL Severe Injury or Major System Damage	II	High	High	High	Medium	Low
MARGINAL Minor Injury or Minor System Damage	III	High	Medium	Medium	Low	Low
NEGLIGIBLE Less Than Minor Injury or System Damage	IV	Medium	Medium	Low	Low	Low

Mitigation actions include:

- The MD530F is crewed with experienced pilots, with current certification.
- All scheduled and required maintenance is current.
- The 2-man crew will have emergency ditching survival gear on board (Figure 4).
- Visual flight following for all over water surveys will be performed.

Figure 5. Safety and Survival Equipment

Safety and survival equipment include:

- One (1) 4-person life raft;
- Individual auto-inflating flotation vests;
- First aid kit;
- Satellite locating EPIRB system with ELT, GPS, 406 Hz systems;
- Handheld VHF radios;
- Signal flares.

USER GUIDE

Trimble® R7 GNSS Receiver
Trimble 5700 GPS Receiver

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USER GUIDE

Trimble® R7 GNSS Receiver
Trimble 5700 GPS Receiver

Version 3.64
Revision A
May 2008

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Release notice

This is the May 2008 release (Revision A) of the *Trimble R7 GNSS and 5700 GPS Receivers User Guide*. It applies to version 3.64 of the Trimble R7 GNSS receiver and the 5700 II GPS receiver.

Product Limited Warranty Information

For applicable product Limited Warranty information, please refer to the Limited Warranty Card included with this Trimble product, or consult your local Trimble authorized dealer.

Product Extended Limited Warranty Information

For applicable product Extended Limited Warranty information, please refer to the Limited Warranty Card included with this Trimble product, or consult your Trimble dealer.

Notices

Class B Statement – Notice to Users. This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes and modifications not expressly approved by the manufacturer or registrant of this equipment can void your authority to operate this equipment under Federal Communications Commission rules.

Canada

This digital apparatus does not exceed the Class B limits for radio noise emissions from digital apparatus as set out in the radio interference regulations of the Canadian Department of Communications.

Le présent appareil numérique n'émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de Classe B prescrites dans le règlement sur le brouillage radioélectrique édicté par le Ministère des Communications du Canada.

Europe

This product has been tested and found to comply with the requirements for a Class B device pursuant to European Council Directive 1999/5/EC on R&TTE, thereby satisfying the requirements for CE Marking and sale within the European Economic Area (EEA). These requirements are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential or commercial environment, and to ensure that the equipment is safe

Australia and New Zealand

This product conforms with the regulatory requirements of the Australian Communications and Media Authority (ACMA) EMC framework, thus satisfying the requirements for C-Tick Marking and sale within Australia and New Zealand.

Taiwan – Battery Recycling Requirements

The product contains a removable Lithium-ion battery. Taiwanese regulations require that waste batteries are recycled.

廢電池請回收

Notice to Our European Union Customers

For product recycling instructions and more information, please go to www.trimble.com/ev.shtml.

Recycling in Europe: To recycle Trimble WEEE (Waste Electrical and Electronic Equipment, products that run on electrical power.), Call +31 497 53 24 30, and ask for the "WEEE Associate". Or, mail a request for recycling instructions to:
Trimble Europe BV
c/o Menlo Worldwide Logistics
Meerheide 45
5521 DZ Eersel, NL

Declaration of Conformity

We, Trimble Navigation Limited,

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declare under sole responsibility that the products:
Trimble R7 GNSS and 5700 GPS receivers
comply with Part 15 of FCC Rules.

Operation is subject to the following two conditions:
(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

Safety Information

This manual describes the Trimble® R7 GNSS and 5700 II GPS receivers. Unless otherwise specified, "the receiver" refers to all receivers covered in this User Guide.

Note – *To determine if you have a* ***5700 II*** *receiver, look underneath for a label that shows the part number and the product name.*

Before you use your receiver, make sure that you have read and understood this publication, as well as all safety requirements.

Warnings and Cautions

An absence of specific alerts does not mean that there are no safety risks involved.

Always follow the instructions that accompany a Warning or Caution. The information they provide is intended to minimize the risk of personal injury and/or damage to the equipment. In particular, observe safety instructions that are presented in the following formats:

WARNING – A Warning alerts you to a likely risk of serious injury to your person and/or damage to the equipment. A warning identifies the nature of the risk and the extent of possible injury and/or damage. It also describes how to protect yourself and/or the equipment from this risk. Warnings that appear in the text are repeated at the front of the manual.

CAUTION – A Caution alerts you to a possible risk of damage to the equipment and/or loss of data. A Caution describes how to protect the equipment and/or data from this risk.

Exposure to radio frequency radiation

You must maintain a minimum separation distance of 20 cm (approximately 8 in.) between yourself and the radiating antenna for this device to satisfy the RF Exposure requirements of the FCC. For mobile operation, the maximum gain of the antenna must not exceed 0 dBi.

For Bluetooth radio

The radiated output power of the internal Bluetooth wireless radio in the Trimble R7 GNSS receiver, is far below the FCC radio frequency exposure limits. Nevertheless, the wireless radio shall be used in such a manner that the Trimble receiver is 20 cm or further from the human body. The internal wireless radio operates within guidelines found in radio frequency safety standards and recommendations, which reflect the consensus of the scientific community. Trimble therefore believes the internal wireless radio is safe for use by consumers. The level of energy emitted is far less than the

electromagnetic energy emitted by wireless devices such as mobile phones. However, the use of wireless radios may be restricted in some situations or environments, such as on aircraft. If you are unsure of restrictions, you are encouraged to ask for authorization before turning on the wireless radio.

Rechargeable Lithium-ion batteries

These receivers use a rechargeable Lithium-ion battery.

WARNING – Do not damage the rechargeable Lithium-ion battery. A damaged battery can cause an explosion or fire, and can result in personal injury and/or property damage.
To prevent injury or damage:
– Do not use or charge the battery if it appears to be damaged. Signs of damage include, but are not limited to, discoloration, warping, and leaking battery fluid.
– Do not expose the battery to fire, high temperature, or direct sunlight.
– Do not immerse the battery in water.
– Do not use or store the battery inside a vehicle during hot weather.
– Do not drop or puncture the battery.
– Do not open the battery or short-circuit its contacts.

WARNING – Avoid contact with the rechargeable Lithium-ion battery if it appears to be leaking. Battery fluid is corrosive, and contact with it can result in personal injury and/or property damage.
To prevent injury or damage:
– If the battery leaks, avoid contact with the battery fluid.
– If battery fluid gets into your eyes, immediately rinse your eyes with clean water and seek medical attention. Do not rub your eyes!
– If battery fluid gets onto your skin or clothing, immediately use clean water to wash off the battery fluid.

WARNING – Charge and use the rechargeable Lithium-ion battery only in strict accordance with the instructions. Charging or using the battery in unauthorized equipment can cause an explosion or fire, and can result in personal injury and/or equipment damage.
To prevent injury or damage:
– Do not charge or use the battery if it appears to be damaged or leaking.
– Charge the Lithium-ion battery only in a Trimble product that is specified to charge it. Be sure to follow all instructions that are provided with the battery charger.
– Discontinue charging a battery that gives off extreme heat or a burning odor.
– Use the battery only in Trimble equipment that is specified to use it.
– Use the battery only for its intended use and according to the instructions in the product documentation.

Other alerts

WARNING – Operating or storing the receiver outside the specified temperature range can damage it. For more information, see Physical specifications, page 8-64.

WARNING – When there is no USB cable connected, or when using the receiver in a harsh environment, keep the USB door closed to keep moisture, dust, and dirt out of the ports. The temperature rating of the receiver applies only when all doors on the receiver are closed.

WARNING – If the card does not seat into the pins correctly, do ***not*** use force or you may damage the pins. Remove the card and carefully reinsert it.

CAUTION – Do not hold down the power button for more than 30 seconds. After 30 seconds, any application files stored in the receiver are deleted.

CAUTION – Upgrading the firmware deletes all application files on the receiver.

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CHAPTER

1

Introduction

Welcome to the *Trimble R7 GNSS and 5700 GPS Receivers User Guide*. This manual describes how to install, set up, and use a Trimble® R7 GNSS receiver or a 5700 II GPS receiver.

Unless otherwise specified, "the receiver" refers to all receivers covered in this User Guide.

***Note** – To determine if you have a **5700 II** receiver, look underneath for a label that shows the part number and the product name.*

Even if you have used other Global Positioning System (GPS) products before, Trimble recommends that you spend some time reading this manual to learn about the special features of your receiver.

If you are not familiar with GPS, visit our website for an interactive look at Trimble and GPS at www.trimble.com

Trimble assumes that you are familiar with the Windows® operating system and know how to use a mouse, select options from menus and dialogs, make selections from lists, and refer to online help.

Related information

An electronic copy of this manual is available in portable document format (PDF) on the receiver CD-ROM. Use Adobe Reader to view the contents of this file.

Other sources of related information are:

- Release notes – the release notes describe new features of the product, information not included in the manual, and any changes to the manual. They are provided as a PDF on the CD. Use Adobe Reader to view the contents of the release notes.
- Registration – register your receiver to automatically receive e-mail notifications of receiver firmware upgrades and new functionality. To register, do one of the following:
  - Run the receiver CD.
  - Register electronically at www.trimble.com.
  - Print the registration form that is on the CD, fill it in, and fax or mail it to the address shown.

    Contact your local Trimble Dealer for more information about the support agreement contracts for software and firmware, and an extended warranty program for hardware.
- Trimble training courses – consider a training course to help you use your GPS system to its fullest potential. For more information, visit the Trimble website at www.trimble.com/training.html.

Technical assistance

If you have a problem and cannot find the information you need in the product documentation, *contact your local Dealer*. Alternatively, request technical support using the Trimble website at (www.trimble.com/support.html).

Your comments

Your feedback about the supporting documentation helps us to improve it with each revision. E-mail your comments to ReaderFeedback@trimble.com.

CHAPTER

2

Overview

In this chapter:

- Features
- Use and Care
- COCOM Limits

This chapter introduces the Trimble® R7 GNSS receiver and the 5700 GPS receiver for GNSS and GPS surveying applications.

Unless otherwise specified, "the receiver" refers to all receivers covered in this User Guide.

The receiver features one-touch logging for ease of use, and five LEDs that enable you to monitor the survey in progress and the available battery capacity.

The Trimble R7 GNSS receiver tracks GPS and GLONASS satellites on both L1 and L2 frequencies. The receiver can record data on an internal CompactFlash card and makes all data available through serial or USB ports.

The 5700 II GPS receiver tracks GPS satellites on both the L1 and L2 frequencies to provide precise position data for land survey applications.

You can use the receiver alone by logging data internally, or as part of a Trimble GPS/GNSS system, which logs GPS data from the receiver to Trimble controllers running Trimble Field software.

Features

The receiver provides the following features:

- Trimble R-track technology, which enables the receivers to track GLONASS, L2C, and L5 (Trimble R7 GNSS receiver)
- Centimeter-accuracy real-time positioning with RTK/OTF data, and up to 10 Hz position updates
- Submeter-accuracy real-time positioning using pseudorange corrections
- Adaptive dual-frequency RTK engine
- WAAS/EGNOS capability (Wide Area Augmentation System/European Geo-Stationary Navigation System)
- Automatic OTF (on-the-fly) initialization while moving
- 1PPS (One Pulse Per Second) output
- Dual event-marker input
- USB port for data transfer
- Type I CompactFlash card for data storage
- Internal charging of batteries (no external battery charger required)
- Three RS-232 serial ports for:
  - NMEA output
  - RTCM SC-104 input and output
  - Trimble Format (CMR+™) input and output
- Two TNC ports for connecting to the GPS/GNSS and radio antennas

Use and Care

The receiver can withstand the rough treatment that typically occurs in the field. However, the receiver is a high-precision electronic instrument and should be treated with reasonable care.

WARNING – Operating or storing the receiver outside the specified temperature range can damage it. For more information, see Physical specifications, page 64.

High-power signals from a nearby radio or radar transmitter can overwhelm the receiver circuits. This does not harm the instrument, but it can prevent the receiver electronics from functioning correctly. Avoid using the receiver within 400 meters of powerful radar, television, or other transmitters. Low-power transmitters such as those used in cellphones and two-way radios normally do not interfere with receiver operations.

For more information, contact your local Trimble distributor.

COCOM Limits

The U.S. Department of Commerce requires that all exportable GPS products contain performance limitations so that they cannot be used in a manner that could threaten the security of the United States. The following limitations are implemented on the receiver.

Immediate access to GPS satellite measurements and navigation results is disabled when the receiver's velocity is computed to be greater than 1000 knots, or its altitude is computed to be above 18,000 meters. The receiver continuously resets until the COCOM situation is cleared.

CHAPTER

3

Setting up the Receiver

In this chapter:

- Parts of the receiver
- Setup guidelines
- Postprocessed setup
- Pole-mounted setup
- Backpack setup
- Other system components

This chapter provides general information on setup, connection, and cabling for the most common uses of the receiver.

Parts of the receiver

All operating controls, ports, and connectors on the receiver are located on its four main panels, as shown in Figure 3.1. This section provides a brief overview of the features of each of these panels.

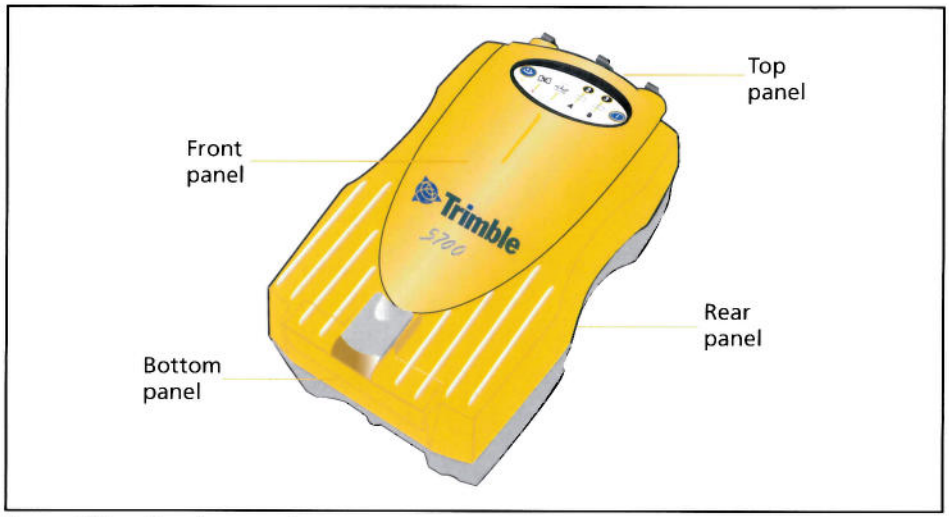


Figure 3.1 Receiver panels

Front panel

Figure 3.2 shows the front panel of the receiver. This panel contains the indicator LEDs, the two buttons, and the catch for the CompactFlash/USB door.

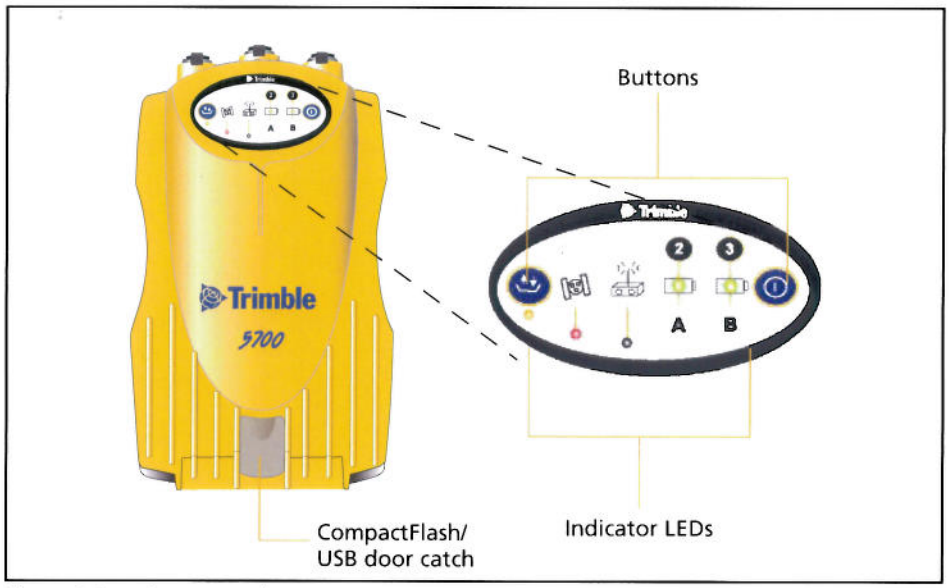


Figure 3.2 Front panel

The two buttons control data logging, data management, power, and settings. For more information, see Button functions, page 36.

The indicator LEDs show the status of logging, power, satellite tracking, and radio reception. For more information, see LED behavior, page 37.

Rear panel

Figure 3.3 shows the rear panel of the receiver. This panel contains a slot for attaching the receiver catch lock, and the catches for the two battery compartments on the bottom panel. The catch lock should already be attached to your receiver.

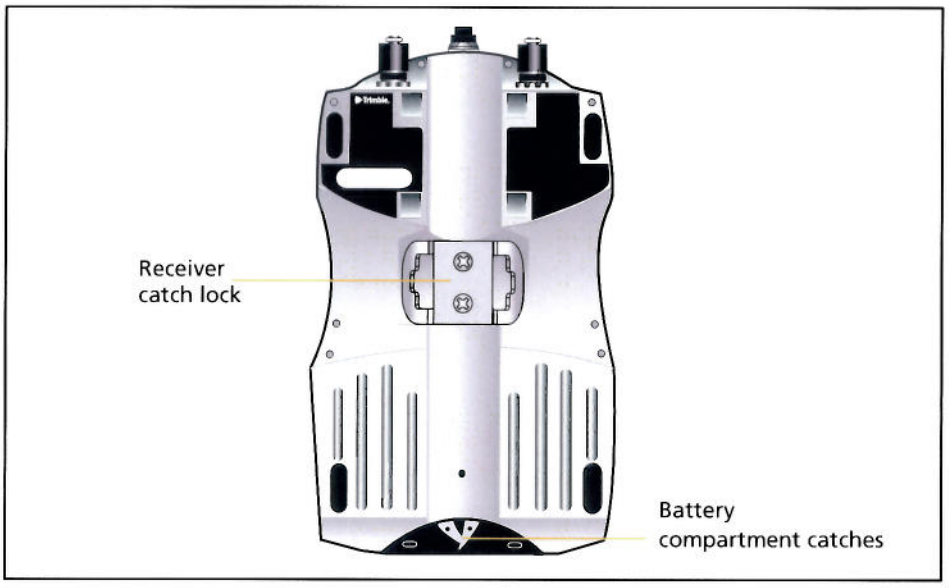


Figure 3.3 Rear panel

To mount the receiver on a pole, attach the receiver bracket to the pole and then insert the catch lock into the bracket. For more information, see Pole-mounted setup, page 24.

Top panel

Figure 3.4 shows the top panel of the receiver. This panel contains the three power/serial data ports and (TNC) ports for GPS and radio antenna connections.

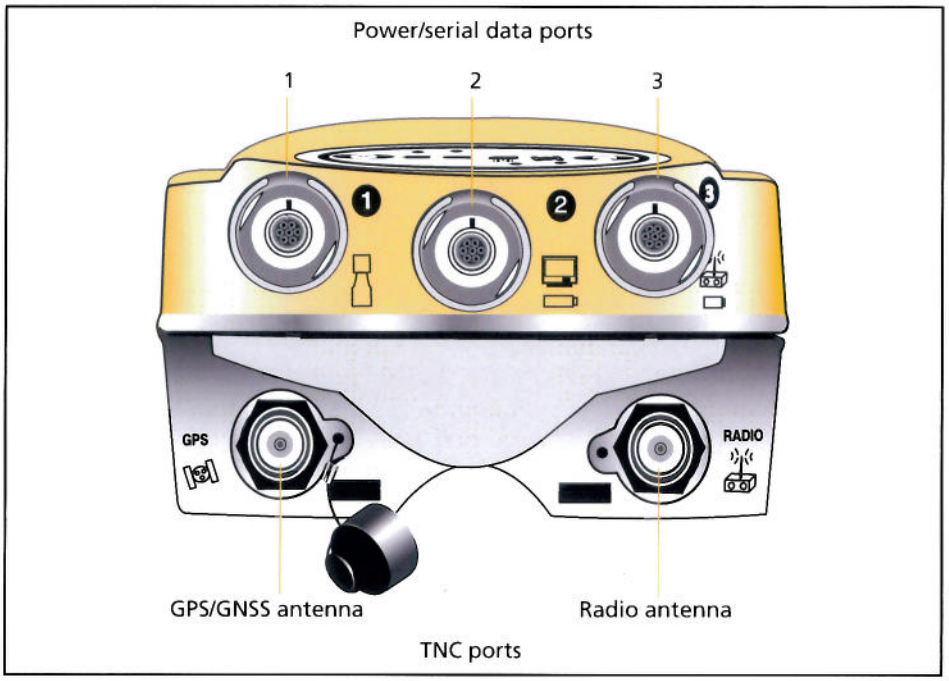


Figure 3.4 Top panel

Each port on the top panel is marked with an icon to indicate its main function, as shown below.

Icon	Name	Connections
	Port 1	Trimble controller, event marker, or computer
	Port 2	Power in, computer, 1PPS, or event marker
	Port 3	External radio, power in
	GPS	GPS/GNSS antenna
	RADIO	Radio communications antenna

The power/serial data ports are all 7 pin 0-shell Lemo connectors. Both Port 2 and Port 3 can accept external power. For more information, see Default settings, page 68 and Cables and Connectors, page 73.

Connect the GPS/GNSS antenna cable to the TNC port marked GPS, and connect the Quarter-wave whip antenna (rubber duck) to the TNC connector marked RADIO. For more information on connecting the receiver, see the following sections in this chapter.

Bottom panel

Figure 3.5 shows the bottom panel of the receiver. This panel contains the USB port, the CompactFlash port, and the compartments for the two internal batteries.

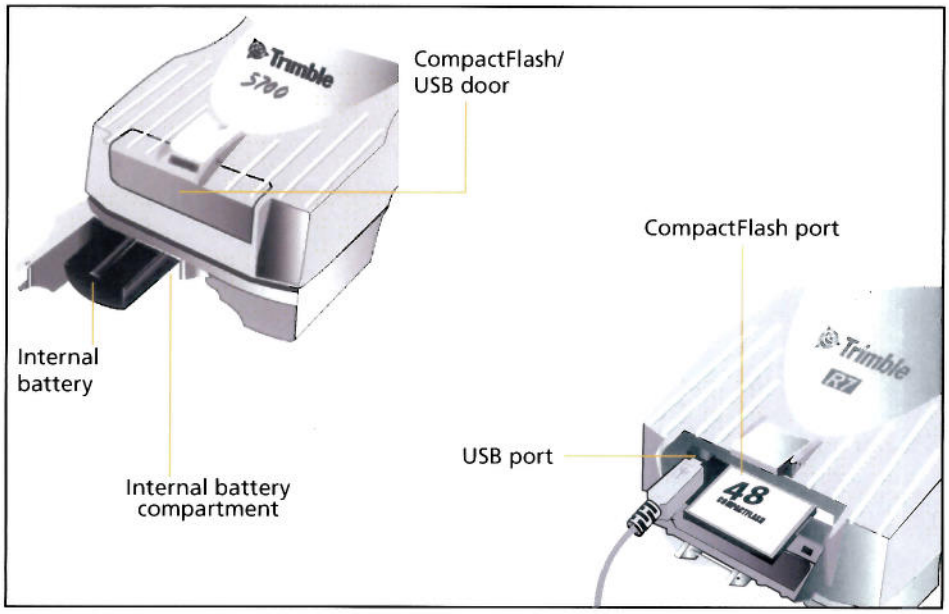


Figure 3.5 Bottom panel

The CompactFlash/USB door conceals the CompactFlash port and USB port. To open the door, push down the catch on the front panel.

WARNING – When there is no USB cable connected, or when using the receiver in a harsh environment, keep this door closed to keep moisture, dust, and dirt out of the ports. The temperature rating of the receiver applies only when all doors on the receiver are closed.

Setup guidelines

When setting up the receiver, follow these guidelines.

Environmental conditions

Although the receiver has a waterproof housing, take reasonable care to keep the unit dry. Avoid exposure to extreme environmental conditions, including:

- Water
- Heat greater than 65° C (149° F)
- Cold less than –40° C (–40° F)
- Corrosive fluids and gases

Avoiding these conditions improves the receiver performance and long-term reliability.

Sources of electrical interference

Avoid the following sources of electrical and magnetic noise:

- Gasoline engines (spark plugs)
- Televisions and computer monitors
- Alternators and generators
- Electric motors
- Equipment with DC-to-AC converters
- Fluorescent lights
- Switching power supplies

General guidelines

WARNING – These receivers use a rechargeable Lithium-ion battery. To avoid personal injury or equipment damage, make sure that you read and understand the Safety Information on page 3 at the front of this manual.

The following guidelines apply whenever you set up your receiver for operation:

- When plugging in a Lemo cable, make sure that the red dots on the receiver port and the cable connector line up. ***Do not*** use force to plug cables in, as this may damage the connector pins.
- When disconnecting a Lemo cable, grasp the cable by the sliding collar or lanyard and pull the cable connector straight out of the port. Do not twist the connector or pull on the cable itself.

- To securely connect a TNC cable, align the cable connector with the receiver receptacle and thread the cable connector onto the receptacle until snug.
- Insert the internal batteries with the battery contacts facing the CompactFlash/USB door. The undersides of the batteries have a center groove for alignment when being inserted into the receiver.

Postprocessed setup

For a postprocessed survey, you only need:

- the receiver
- one of the following antennas:
  - Zephyr™ or Zephyr Geodetic™
  - Zephyr 2 or Zephyr Geodetic 2 (Trimble R7 GNSS receiver only)
- a GPS/GNSS antenna cable

Other equipment, as described below, is optional.

To set up the receiver for a postprocessed survey:

1. Set up the tripod with the tribrach and antenna adapter over the survey mark.

   Instead of a tripod, you can use a range pole with a bipod. However, Trimble recommends that you use a tripod for greater stability.
2. Mount the antenna on the tribrach adapter.
3. Use the tripod clip to hang the receiver on the tripod.
4. Connect the GPS/GNSS antenna cable to the Zephyr antenna.
5. Connect the other end of the GPS/GNSS antenna cable to the TNC port on the receiver.
6. If external power is required, connect a battery with an 0-shell Lemo connection to Port 2 or Port 3 on the receiver.

Figure 3.6 shows the receiver postprocessed setup.

Figure 3.6 Postprocessed setup

***Note** – Instead of hanging the receiver on the tripod, you can place the receiver in its base case. Run the antenna cable out of the portal in the side of the base case to the antenna so that the case can stay closed while the receiver is running.*

Pole-mounted setup

Do the following:

1. Mount the Zephyr antenna. See page 24.
2. Mount the receiver on the pole. See page 25.
3. Attach the controller. See page 26.

Mounting the Zephyr antenna

1. Screw the antenna to the 5/8-11 threads on the top of the range pole.
2. Connect the TNC-to-TNC GPS cable to the port on the top of the receiver.
3. Connect the TNC-to-TNC GPS cable to the antenna.

Mounting the receiver on the pole

1. Attach the receiver bracket to the pole:

   a. Place the bracket against the pole, approximately 0.5 m from the ground.

Note – *If you are using a 1" diameter pole, flip the bracket insert around inside the bracket, as shown in Figure 3.7.*

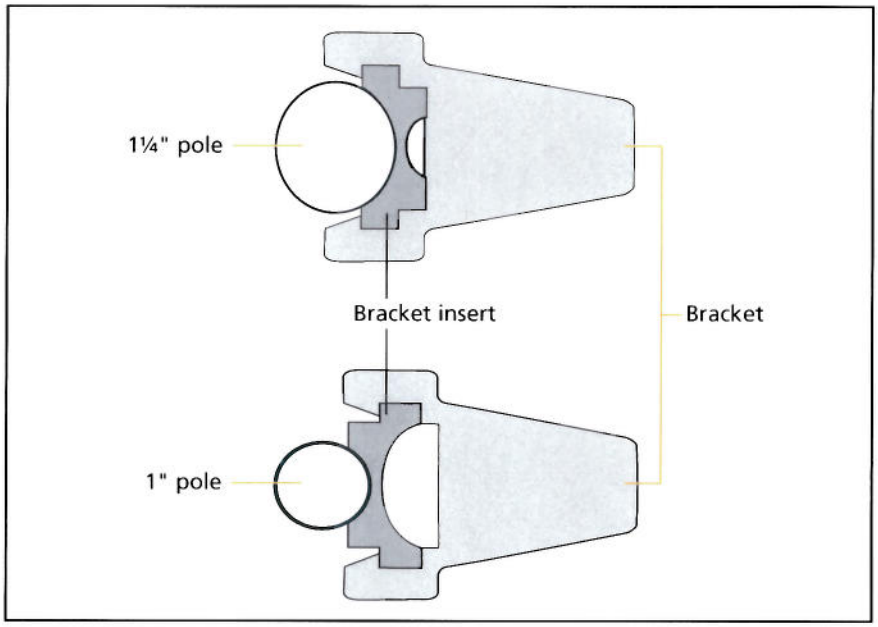


Figure 3.7 Receiver bracket insert

   b. Close the gates of the bracket around the pole.

   c. Seat the base of the clip lock in the opposite gate.

   d. Lock the clip lock.

      If the clip lock is too tight to be locked, turn it one or two turns counterclockwise and try again. If it is too loose, turn it one or two turns clockwise and try to lock it again.

2. Mount the receiver on the bracket:

   a. Pull the bracket side locks in towards the pole.

   b. Set the receiver catch lock in the bracket.

   c. Holding the receiver in the bracket, pull the side locks back to their original positions, as shown in Figure 3.8.

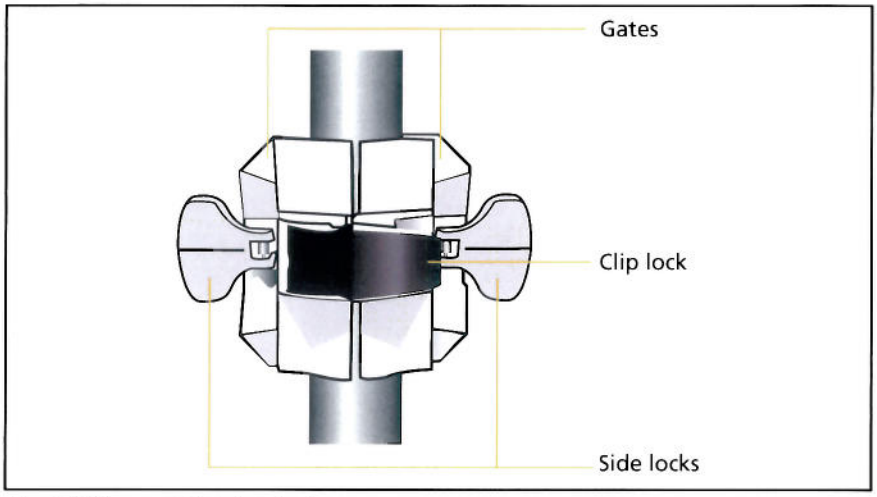


Figure 3.8 receiver bracket

3. Connect the quarter-wave whip ("rubber duck") antenna to the radio port on top of the receiver.
4. If necessary, adjust the position of the receiver to remove cable slack from the TNC GPS antenna cable.

Mounting the controller

1. Mount the TSC2® controller bracket on the pole:
   a. Place the bracket against the pole at a comfortable height.
   b. Rotate the pole clamping screw on the controller bracket until tight.
   c. Place the controller into the cradle assembly and tighten the clamping mechanism.
   d. If there are any cables running down the pole, run them through the machined groove on the inside of the controller bracket.
   e. To put the controller in the preferred position for operation, press the spring-loaded release button on the cradle, pull the assembly outward, and then rotate the cradle assembly to the required angle. To rest the cradle in the proper position, line up the alignment pin on the cradle with the hole in the controller bracket and then push it inward until the release button locks.

Note – *If you use Bluetooth® wireless technology with the Trimble R7 GNSS receiver, omit steps 2 and 3.*

2. Connect the DB9-to-0-shell Lemo cable to the controller.
3. Connect the other end of the cable to Lemo Port 1 on the receiver.
4. Place the hand grip below the controller bracket (or above it, depending on the position of the bracket), with the cables running through the grip.

5. Secure any loose cables, using the velcro cable ties.

Figure 3.9 shows the completed pole-mounted setup.

Figure 3.9 Pole-mounted setup

Backpack setup

To set up the receiver for use in a backpack:

1. Insert the receiver into the backpack with the ports on the top panel facing upwards and the front panel facing outwards. Secure the receiver around the middle with the velcro strap.
2. Attach the Zephyr™ antenna to a range pole.
3. Attach the whip antenna mount to one of the fittings on the top of the backpack.
4. The backpack has a feedthrough on both sides at the top and on both sides near the bottom to allow cables to be positioned out of the way of the main zipper. Run the radio communications cable through at the top, and connect it to the blue TNC port on the receiver.
5. Connect the straight end of the yellow GPS cable to the yellow TNC port on the receiver.

6. Run the right-angle connector on the yellow GPS cable through the top or side slot on the backpack, and then connect it to the Zephyr antenna.
7. Connect the DB9-to-0-shell Lemo cable to Port 1 on the receiver.
8. Run the DB9 cable through the side slot of the backpack and then connect it to the controller.

***Note** – Trimble does not recommend using a Bluetooth® connection for a backpack setup.*

Figure 3.10 shows the backpack setup.

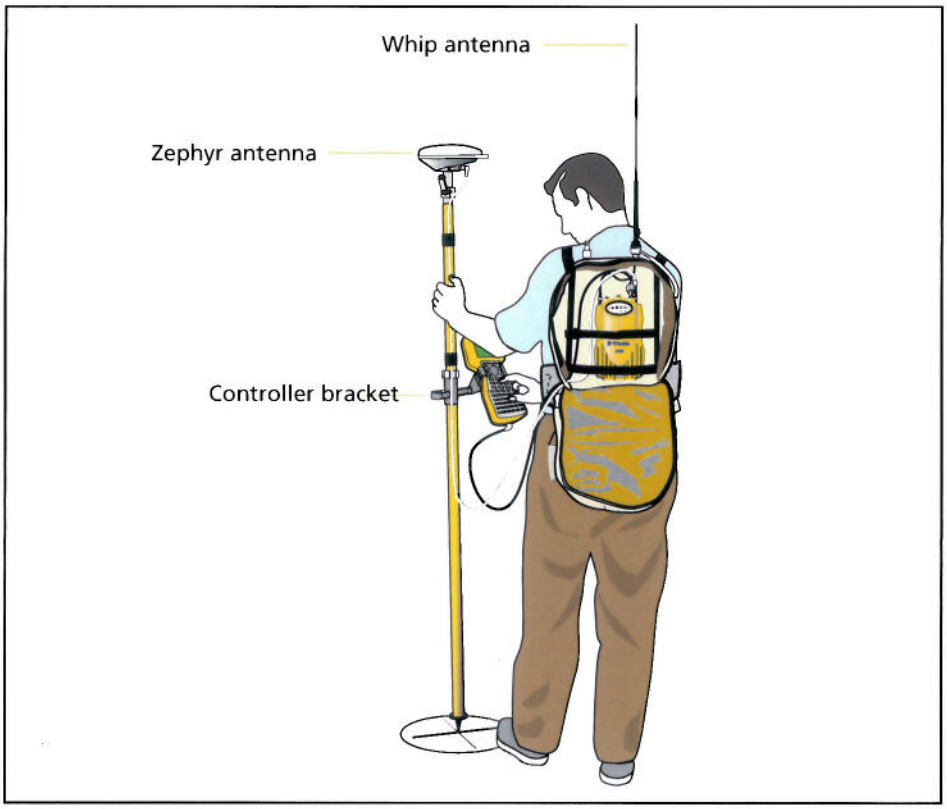


Figure 3.10 Backpack setup

Other system components

This section describes optional components that you can use with the receiver.

Radios

Radios are the most common data link for Real-Time Kinematic (RTK) surveying. The receiver is available with an internal receive-only radio that uses a UHF frequency band in the 400 MHz to 500 MHz range. You can also connect an external radio to Port 3, whether or not the internal radio is installed.

The receiver supports the following Trimble base radios when using the internal receiver radio:

- Trimble HPB450
- Trimble PDL450
- Receiver internal 450 MHz transmitter
- TRIMMARK™ 3 radio
- SiteNet™ 450 radio

Internal radio setup

To configure the receiver optional internal radio, use one of the following:

- The GPS Configurator software
- The WinFlash utility
- The Trimble Survey Controller™ software
- The Trimble Digital Fieldbook™ software

For more information, refer to the documentation for these applications.

By default, the internal radio has only a few "test" frequencies installed at the factory. You can program the receive frequencies using the WinFlash utility. For more information, see The WinFlash utility, page 58.

External radio setup

To use an external radio with the receiver, you need to set up an external power source for the radio:

1. Connect one end of the GPS antenna cable to the TNC port on the receiver.
2. Connect the other end of the GPS antenna cable to one of the following antennas:
   - Zephyr or Zephyr Geodetic
   - Zephyr 2 or Zephyr Geodetic 2 (Trimble R7 GNSS receiver only)
3. Connect the external radio to Port 3 on the receiver.
4. Connect a radio antenna to the external radio.
5. Connect an external power source to Port 2 on the receiver.

   Note – *External rover radios must have their own power source because the internal Lithium-ion batteries do not supply enough voltage. Alternatively, supply external power to Port 2 of the receiver, and enable power out on Port 3.*
   Base (transmit/receive) radios must have their own power source because of their high power consumption.

   Alternatively, you can apply external power directly to the radio, if it supports it.

You can use a 10 Ah battery, a 6 Ah battery, or camcorder batteries. The choice of power supply depends on the application, and whether you are using the radio as a base or rover radio. For more information about the power capabilities of the receiver, see Batteries and power, page 40.

6. Configure the external radio using Trimble Survey Controller software. Alternatively, you can configure an external radio using the WinFlash utility or the configuration software supplied with the radio.

   For more information, refer to the *Trimble Survey Controller User Guide* or the appropriate Help.

7. Set up any other equipment as required, depending on whether you are using the radio as a reference or a rover radio.

Cellular modems

You can use a cellular modem instead of a radio as your data communications link. Cellular modems and other radio links can be used to extend the limits of your surveys.

To connect a cellular modem to a receiver, you need the following:

- A receiver
- A custom-designed cellular modem, or a cellphone that can transmit and receive data
- Serial (cellphone to DB9) cable (supplied with the cellular modem or phone)
- Trimble DB9 to 0-shell Lemo cable

Note – *This cable is suitable only if flow control can be disabled on the cellular modem. If the cellular modem does not support this functionality, a special cable is required. For more information, refer to the document Using Cellular and CDPD Modems for RTK, which is available from your local Trimble Reseller.*

Figure 3.11 shows the components required to connect a cellphone to a receiver.

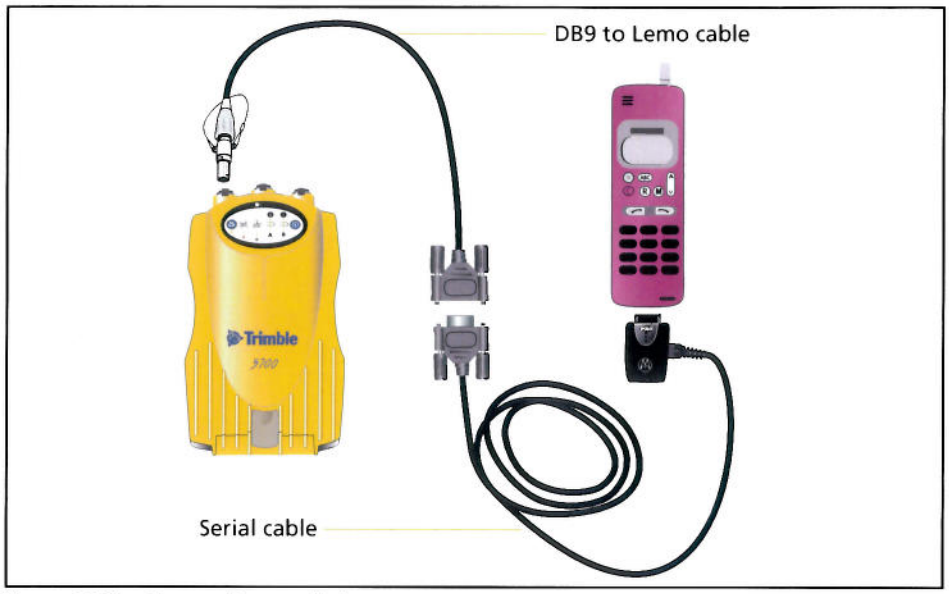


Figure 3.11 Connecting a cellphone

For more information on using a cellular modem as a data link, refer to the *Trimble Survey Controller User Guide*.

Antennas

The receiver should normally be used with one of the following antennas, which have been designed specifically for them:

- Zephyr or Zephyr Geodetic (5700 receiver)
- Zephyr 2 or Zephyr Geodetic 2 (Trimble R7 GNSS receiver)

Use Figure 3.12 as a guide for measuring the height of the Zephyr and Zephyr Geodetic antennas. The Zephyr antenna is designed to be measured to the top of the notch. The Zephyr Geodetic (shown) has been designed to be measured to the bottom of the notch.

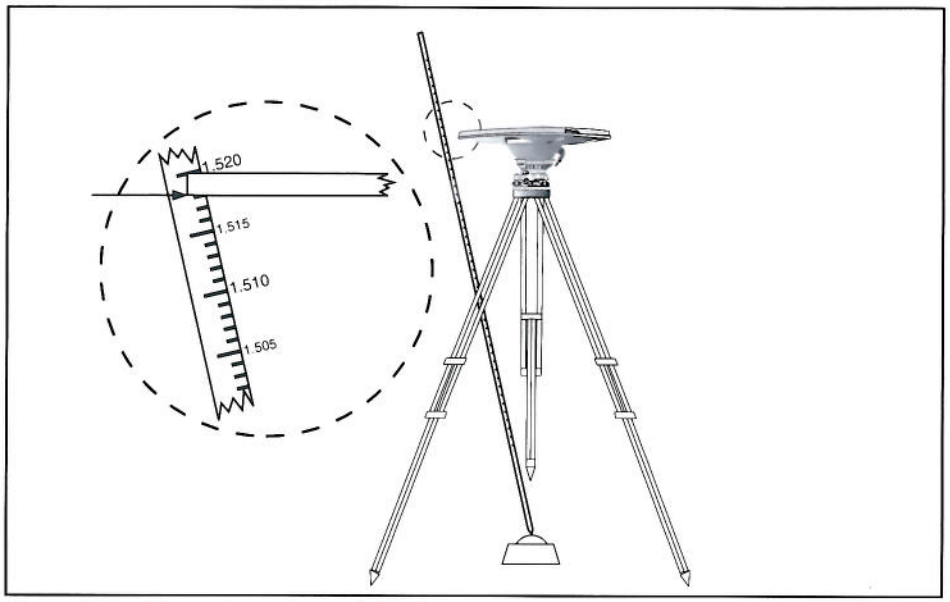


Figure 3.12 Measuring antenna height

Some models of antennas, such as the Choke Ring or older Micro-Centered™ L1/L2 antennas, need more power to operate than the Zephyr models. To configure the receiver to output more power on the antenna port, select the correct antenna type in GPS Configurator, or through the Trimble controller. For information on how to do this, contact your local Trimble Service Provider.

CompactFlash cards

The receiver logs data internally on a CompactFlash card. However, it only support the Type I CompactFlash card. Trimble recommends that you use an industrial-rated CompactFlash card, as commercial cards have a limited operating temperature range.

Before logging data to a CompactFlash card, format the card to ensure the integrity of the file system. To format the card, insert it in the receiver and then hold down the power button for 30 seconds.

Note – *Make sure that you format your CompactFlash card in the receiver. This prevents data on the card from being corrupted if the card is removed while data is being logged. Formatting the card in your computer may cause data corruption, or loss of data.*

When inserting the card, make sure that it slides into the card slot properly.

CAUTION – The receiver allows for more than 500 files on the CompactFlash card, regardless of the card's capacity. The file names must be in 8.3 format, otherwise, files copied to the CompactFlash card may cause data corruption or loss of data when logging.

CAUTION – If the card does not seat into the pins correctly, do ***not*** use force or you may damage the pins. Remove the card and carefully reinsert it.

CHAPTER

4

General Operation

In this chapter:

- Front panel controls
- Button functions
- LED behavior
- Starting and stopping the receiver
- Logging data
- Resetting to defaults
- Formatting a CompactFlash card
- Batteries and power

All the controls that you need for general receiver operation are on the front panel.

For more information about other receiver panels, see Parts of the receiver, page 18.

Front panel controls

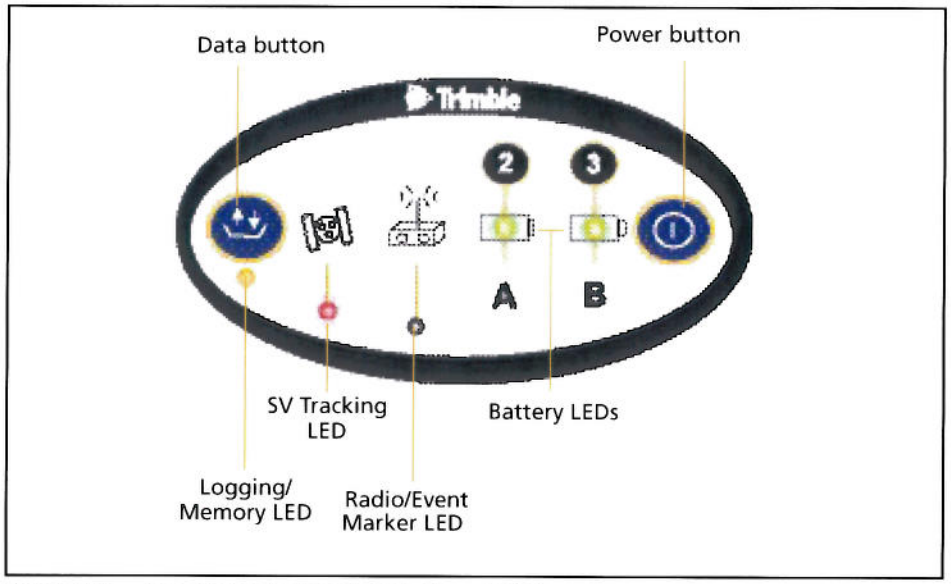


Figure 4.1 Receiver front panel controls and LEDs

Button functions

The receiver has only two buttons: the Power button ⏻ and the Data button ⇅

Press ⏻ to switch the receiver on or off, and to perform data management functions such as deleting files or resetting the receiver.

Press ⇅ to start or stop logging. This button is effective only when the receiver is switched on and has completed any power-up and initialization tasks.

Table 4.1 describes the main functions of the two buttons.

Table 4.1 Button functions

Action	Power button	Data button
Turn on the receiver	Press	
Turn off the receiver	Hold for 2 seconds	
Start logging data internally		Press
Stop logging data internally		Hold for 2 seconds
Delete the ephemeris file	Hold for 15 seconds	
Reset the receiver to factory defaults	Hold for 15 seconds	
Delete application files	Hold for 30 seconds	
Format the CompactFlash card	Hold for 30 seconds	

Note – *The term "press" means to press the button and release it immediately. The term "hold" means to press the button and hold it down for the given time.*

LED behavior

The five LEDs on the top panel of the receiver indicate various operating conditions. Generally, a lit or slowly flashing LED indicates normal operation, an LED that is flashing quickly indicates a condition that may require attention, and an unlit LED indicates that no operation is occurring. The following table defines each possible LED state.

The term ...	means that the LED ...
Flash	is lit briefly every 3 seconds
Slow flash	alternates slowly between being lit and unlit
Fast flash	alternates rapidly between being lit and unlit
On	is lit
Off	is unlit

Logging/memory LED

The yellow Logging/memory LED below the button indicates the status of data logging and memory usage.

Behavior	Meaning
On	Data is being logged.
Slow flash	Enough FastStatic data has been logged. Alternatively, if the red SV Tracking LED is on solid at the same time and the other LEDs are off, the receiver is in Monitor mode. Turn off the power and then turn it on again to return to normal operation.
Fast flash	Data is being logged but memory is low.
Very slow flash	The receiver is in Sleep mode, and will wake up five minutes before the scheduled start time of a timed application file.
Off	Data is not being logged.

SV Tracking LED

The red SV Tracking LED below the SV icon indicates the status of satellite tracking.

Behavior	Meaning
Slow flash	Tracking four or more satellites.
Fast flash	Tracking three or fewer satellites.
Off	Not tracking any satellites.
On	The receiver is in Monitor mode, and is checking for new firmware to install.

Radio LED

The green Radio LED below the Radio icon indicates the status of data input and output.

Behavior	Meaning
Slow flash	A data packet or event marker has been received.

Battery 1 LED and battery 2 LED

The Battery LEDs inside the two Battery icons indicate the status of the two internal batteries, or the power sources connected on Ports 2 and 3.

By default, each battery LED indicates the status of the external power source on the corresponding port. If no external source is detected, each LED indicates the status of an internal battery. The color of the LED indicates whether the power source is currently in use (green) or is on standby (yellow).

Color	Meaning	Behavior	Meaning
Green	Power source is in use	On	Healthy
		Fast flash	Low power
		Off	No power source is present
Yellow	Power source is on standby	On	Healthy
		Fast flash	Low power
		Flash	Dead
		Off	No power source is present

Starting and stopping the receiver

To turn on the receiver, press ⏻.

To turn off the receiver, hold down ⏻. The SV LED turns on, and then turns off after two seconds. When the LED turns off, release ⏻; the receiver turns off.

Logging data

You can log data to the CompactFlash card in the receiver, or to a Trimble controller.

Logging internally

The receiver logs GPS data internally on a CompactFlash card. Use Trimble Business Center to download the *.T01 formatted files directly from the CompactFlash card to the office computer. Alternatively, you can use the Trimble Data Transfer utility to transfer logged data files to your office computer. The transferred files are in Trimble DAT (.dat) format.

If you use the Data Transfer utility to download the internally-logged files, you lose any collected GLONASS data. Consider this if you plan to use the Trimble Geomatics Office software to process the *.dat files because that software does not process GLONASS data.

If you have the Trimble Business Center software, the *.T01 file that is stored on the receiver can be directly downloaded. The *.T01 files will contain any collected GLONASS data. Trimble Business Center software can process GLONASS data, if you have purchased that option.

CAUTION – The receiver allows for more than 500 files on the CompactFlash card, regardless of the card's capacity. The file names must be in 8.3 format, otherwise, files copied to the CompactFlash card may cause data corruption or loss of data when logging.

Data is logged using the current logging settings configured in the receiver. Data files logged internally are named automatically.

To begin internal logging, press . The Logging/memory LED lights up.

To stop logging, hold down for at least two seconds. The Logging/memory LED turns off.

Note – *When the CompactFlash card is full, if auto-delete is not enabled, the receiver stops logging data, and the Logging/memory LED turns off. Existing data files are not overwritten.*

Approximate storage requirements for different logging rates are shown below. The values shown are for a one-hour logging session with six satellites visible.

Logging rate	Minimum memory required
10 Hz	2,588 KB
1 Hz	335 KB
5 seconds	87 KB
15 seconds	37 KB

Note – *If power is lost, or the CompactFlash card is removed while logging, the file system is designed so that a maximum of ten seconds of data will be lost, regardless of the logging rate.*

Logging to a Trimble controller

When the receiver is connected to a Trimble controller, you can log GPS data from the receiver to the controller, or to a data card inserted in the controller. When you use a Trimble controller, you do not use the receiver's controls. Instead, you use the controller functions to set logging options, specify filenames, and to control when logging occurs.

Controller software job files and the corresponding raw data files can be transferred to an office computer using the Trimble Data Transfer utility.

For more information on logging data from a receiver using a Trimble controller, refer to the user guide for your particular controller.

Resetting to defaults

CAUTION – If you hold down ⊕ for more than 30 seconds, any application files stored in the receiver are deleted and the CompactFlash card is reformatted.

To reset the receiver to its factory default settings, hold down ⊕ for at least 15 seconds.

Resetting the receiver to its factory defaults also deletes any ephemeris file in the receiver.

For more information, see Chapter 9, Default Settings.

Formatting a CompactFlash card

CAUTION – Formatting a CompactFlash card while it is in the receiver deletes all the data files on the card.

To format a CompactFlash card for use in the receiver, insert the card in the CompactFlash port and then hold down ⊕ for at least 30 seconds. After 15 seconds, the receiver is reset to its factory defaults, and any ephemeris file is deleted. After 30 seconds, any files stored on the card are deleted and the CompactFlash card is reformatted.

Note – *When you use ⊕ to format the CompactFlash card, a quick format is performed. A quick format reformats the card for use with the receiver and deletes all data on the card. A full format checks the card for errors or bad sectors, and is only necessary if the card is corrupted. To perform a full format, use the GPS Configurator software. For more information, see* *The GPS Configurator software, page 58*.

Batteries and power

WARNING – Do not damage the rechargeable Lithium-ion battery. A damaged battery can cause an explosion or fire, and can result in personal injury and/or property damage. To prevent injury or damage:
– Do not use or charge the battery if it appears to be damaged. Signs of damage include, but are not limited to, discoloration, warping, and leaking battery fluid.
– Do not expose the battery to fire, high temperature, or direct sunlight.
– Do not immerse the battery in water.
– Do not use or store the battery inside a vehicle during hot weather.
– Do not drop or puncture the battery.
– Do not open the battery or short-circuit its contacts.

The receiver can be powered either by its two internal batteries or by an external power source connected to Port 2 or Port 3. The charge provided by the internal batteries depends on the type of survey and operating conditions.

The external power source is always used in preference to the internal batteries. When there is no external power source connected, or if the external power supply fails, the internal batteries are used. The internal batteries are drained in turn, and the receiver automatically switches to the full battery when the first battery is drained.

If no external power is supplied and both internal batteries are drained, none of the data that you have logged is lost. When internal or external power is restored, the receiver restarts in the same state as when power was lost. For example, if the receiver was logging data, the data file is not corrupted, and when power is restored the receiver resumes logging with the same settings as before.

The power supply that comes with the receiver charges the internal batteries while they are still in the receiver. To do this, connect the power supply to the power/serial data cable, connect the cable to Port 2 on the receiver and then connect the power supply to an AC power source, as shown in Figure 4.2.

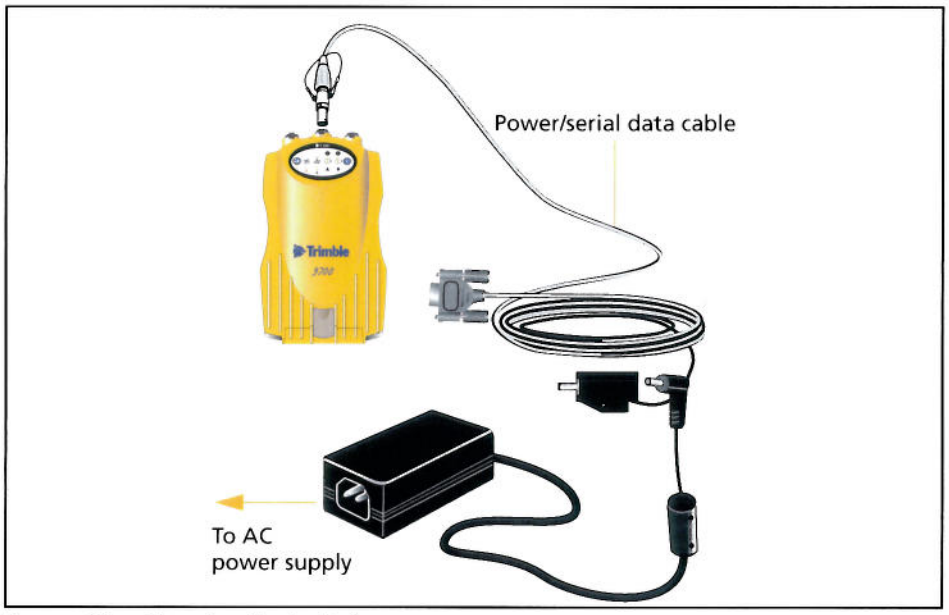


Figure 4.2 Charging the batteries

The two internal batteries take approximately eight hours to charge. They are charged individually, so each battery takes approximately four hours to charge. The internal batteries start charging whenever an external power supply of greater than 15 V is detected.

WARNING – Avoid contact with the rechargeable Lithium-ion battery if it appears to be leaking. Battery fluid is corrosive, and contact with it can result in personal injury and/or property damage.
To prevent injury or damage:
– If the battery leaks, avoid contact with the battery fluid.
– If battery fluid gets into your eyes, immediately rinse your eyes with clean water and seek medical attention. Do not rub your eyes!
– If battery fluid gets onto your skin or clothing, immediately use clean water to wash off the battery fluid.

Each receiver in your system is supplied with two internal Lithium-ion batteries. To charge both sets of batteries, connect both receivers to power supplies as shown in Figure 4.2.

Battery charging and storage

All battery types discharge over time when they are not being used. Batteries also discharge faster in colder temperatures. If a Lithium-ion battery is to be stored for long periods of time, make sure it is fully charged before storing and re-charged at least every three months.

WARNING – Charge and use the rechargeable Lithium-ion battery only in strict accordance with the instructions. Charging or using the battery in unauthorized equipment can cause an explosion or fire, and can result in personal injury and/or equipment damage.
To prevent injury or damage:
– Do not charge or use the battery if it appears to be damaged or leaking.
– Charge the Lithium-ion battery only in a Trimble product that is specified to charge it. Be sure to follow all instructions that are provided with the battery charger.
– Discontinue charging a battery that gives off extreme heat or a burning odor.
– Use the battery only in Trimble equipment that is specified to use it.
– Use the battery only for its intended use and according to the instructions in the product documentation.

Charging the Lithium-ion battery

The rechargeable Lithium-ion battery is supplied partially charged. Charge the battery completely before using it for the first time. If the battery has been stored for longer than six months, charge it before use.

To protect the battery from deep discharge (5 V or less), the receiver is designed to switch batteries or cease drawing power when the battery pack discharges to 5.9 V.

A battery that has reached the deep discharge level cannot be recharged and must be replaced. The following recommendations provide optimal performance and extend the life of your batteries:

- Fully charge all new batteries before use.
- Do not allow the batteries to discharge below 5 volts.

- Keep all batteries on continuous charge when not in use. Batteries may be kept on charge indefinitely without damage to the receiver or batteries.
- Do not store batteries in the receiver or external charger unless power is applied.
- If you must store the batteries, fully charge them before storing and then recharge them at least every three months.

Disposing of the rechargeable Lithium-ion battery

Discharge the Lithium-ion battery before disposing of it. When disposing of the battery, be sure to do so in an environmentally sensitive manner. Adhere to any local and national regulations concerning battery disposal or recycling.

Operating with the controller

If the receiver is being powered by its internal batteries, it does not supply power to the controller when they are connected. The receiver and the Trimble controller must be charged using their own power supplies with connections to the AC power supply from the wall.

Power output

If the receiver is being supplied with power from an external source, power is automatically output on Port 1. Port 1 outputs a maximum voltage of 20 V, even if the input voltage is higher.

You can use GPS Configurator or Trimble Survey Controller software to enable power output on Port 3. Port 3 can be enabled for power output regardless of whether power is supplied internally or externally.

On Port 3, the output voltage is approximately 0.5 V less than the input voltage. For example, if power is being supplied from the internal Lithium-ion batteries, the maximum battery voltage is 8.4 V, so the maximum output voltage is 7.9 V.

Note – *When you start a survey using the Trimble Survey Controller software, and you are using an external radio, the software automatically enables power output on Port 3.*

Firmware

A receiver's *firmware* is the program inside the receiver that makes the receiver run and controls the hardware. You can upgrade the firmware for the receiver using the WinFlash utility provided on the receiver CD. For more information, see The WinFlash utility, page 58.

CAUTION – Downgrading the firmware deletes all application files on the receiver.

CHAPTER

5

Configuration

In this chapter:

- Configuring the receiver in real Time
- Configuring the receiver using application files
- Application files

The receiver has no controls to change settings. To configure the receiver, use external software, such as GPS Configurator, WinFlash, Trimble Survey Controller, or Trimble Digital Fieldbook.

To configure the receiver, do one of the following:

- Configure the receiver in real time
- Apply the settings in an application file

This chapter provides a brief overview of each of these methods, and describes the contents and use of application files.

Configuring the receiver in real Time

The GPS Configurator, Trimble Survey Controller, and Trimble Digital Fieldbook software support real-time configuration of the receiver.

When you configure the receiver in real time, you use one of these software applications to specify which settings you want to change. When you apply the changes, the receiver settings change immediately.

Any changes that you apply to the receiver are reflected in the current application file, which is always present in the receiver. The current application file always records the most recent configuration, so if you apply further changes (either in real time or using an application file) the current file is updated and there is no record of the changes that you applied originally.

For more information on configuring the receiver in real time, see Chapter 7, Software Utilities.

Configuring the receiver using application files

An application file contains information for configuring a receiver. To configure a receiver using an application file, you need to create the application file, transfer it to the receiver, and then apply the file settings. The GPS Configurator software does this for you automatically when you work with configuration files.

For more information on applying application files, see Chapter 7, Software Utilities.

Application files

Application files store a receiver's configuration for use at a later time.

You can store up to ten different application files in battery-backed memory on the receiver. You can apply an application file's settings at the time it is transferred to the receiver, or at any time afterwards.

Special application files

The receiver has three special application files, which control important aspects of the receiver's configuration.

Default application file

The default application file (Default.cfg) contains the original receiver configuration, and cannot be changed. This file configures the receiver after it is reset. To reset the receiver, hold down the Power button for at least 15 seconds, or use the reset option in the GPS Configurator software.

For more information, see Default settings, page 68.

Although you cannot change or delete the default application file, you can use a power up application file to override any or all of the default settings.

Current application file

The current application file (Current.cfg) reflects the current receiver configuration. Whenever you change the receiver's configuration, either in real time or by applying an application file, the current file changes to match the new configuration.

You cannot delete the current file or change it directly, but every change to the receiver's current configuration is applied to the current file as well.

When you turn off the receiver then turn it on again, all the settings from the current application file are applied, so you do not lose any changes that you have made. The only exceptions are the following logging parameters:

- Logging rate
- Position rate
- Elevation mask

These parameters are always reset to the factory default values whenever the receiver is switched off.

Power up application file

The power up application file (Power_up.cfg) is optional. if a power up file is present, its settings are applied whenever the receiver is turned on.

In this file, you can specify that the receiver is reset to defaults before the power up settings are applied. This ensures that restarting the receiver always results in the same configuration. This method is useful for defining "default" settings for the receiver that differ from those in the default file, which cannot be changed.

Alternatively, you can specify that the power up settings are applied immediately after the current application file's settings have been applied. Restarting the receiver results in a configuration that uses your default settings for the options you define in the power up file, but the current settings for all other options.

By default, there is no power_up application file on the receiver. To use a power up application file, you must create and save a power_up application file in the GPS Configurator software. If you save this file to disk, the file is called power_up.cfg. The extension .cfg is used by convention to identify application files on the office computer. when you transfer this file to the receiver, the file is saved on the receiver as power_up, and becomes the new power up file.

Timed application files

A timed application file contains a Timed Activation record which specifies when this file is to be applied. The main use of a timed application file is to automatically start or stop logging at a predefined time.

The Timed Activation record specifies:

- the UTC date and time when the application file is to be applied for the first time
- the interval at which the file is to be reapplied

If you do not specify a repeat interval, the settings are applied only once, at the specified time. If the file specifies a repeat interval, the file's settings are reapplied at the specified interval until the file is deactivated.

***Note** – If the receiver is logging continuously, the current logging takes precedence over any timed application file stored in the receiver.*

Defining timed application files

To send timed application files to a receiver, set up scheduled survey sessions in the GPS Configurator software. You can define multiple sessions, each specifying:

- basic logging parameters (data logging rate, position logging rate, and elevation mask)
- a starting time
- a duration

When you apply the current settings in the GPS Configurator software, each defined survey session is sent to the receiver as a pair of timed application files: the first includes the logging settings and start time, and the second contains settings that stop logging at the end time (which is calculated automatically from the duration you specify).

For more information on scheduled survey sessions, refer to the GPS Configurator Help.

The receiver can store up to 10 application files, so you can define a maximum of 5 scheduled survey sessions (5 pairs of start/stop timed application files).

Sleep mode

Whenever you press P to turn off the receiver, the receiver checks for a timed application file that is due to be activated in the future. If one exists, the receiver goes into Sleep mode instead of turning off.

In Sleep mode, the yellow Logging/memory LED flashes every three seconds. The receiver wakes up five minutes before the scheduled activation time, so that it is ready to begin logging at the scheduled time.

Applying application files

An application file's settings do not affect the receiver's configuration until you ***apply*** the application file. You can do this at the same time that you save the file. Alternatively, save the file on the computer or in the receiver, then open it later and apply its settings.

Note – *If the application file is a timed file, its settings do not take effect as soon as you apply the file, but at the time that the file specifies for its activation.*

Storing application files

You can store application files that you create in the GPS Configurator software on the receiver and on the computer. For example, each file can represent a different user sharing the same receiver, or a particular mode of operation or survey style. Saving application files on your computer as well as in your receiver is optional, but it is useful because:

- it gives you a permanent copy of the settings you have sent to a receiver, for audit or your own reference.
- you can use the same file to configure multiple receivers identically.
- you can use an existing application file as a template to create other application files with similar settings.

Naming application files

The application filename in the office computer and in the receiver is always the same. This makes it easier to recognize and keep track of your application files.

When you change the name of the application file in the receiver, this changes the application filename on your computer. When you transfer an application file from the receiver and save it to the computer, the system renames the file to match the internal receiver file. However, if you use Windows Explorer, for example, to change the .cfg filename on the computer, this ***does not*** change the internal receiver filename. This means that the GPS receiver does not recognize the change to the filename on the computer.

CHAPTER

6

Transferring Data

In this chapter:

- Connecting to the office computer
- Transferring data
- Transferring files from a CompactFlash card
- Deleting files in the receiver
- Supported file types

The receiver keeps satellite measurements and other data in files stored on a CompactFlash card. These files cannot be processed until you transfer them to your office computer.

Note – *The receiver supports more than 500 files on the CompactFlash cards.*

When you return to the office with a completed survey, transfer the field data to a computer that has the Trimble Business Center software installed. You can then process the survey data in the Trimble Business Center software to produce baselines and coordinates.

Connecting to the office computer

The receiver has three serial (COM) ports and one USB port to connect to the office computer. A USB connection is up to ten times faster than normal serial communications.

Use the standard power/serial data cable to connect the receiver to the computer, as shown in Figure 6.1.

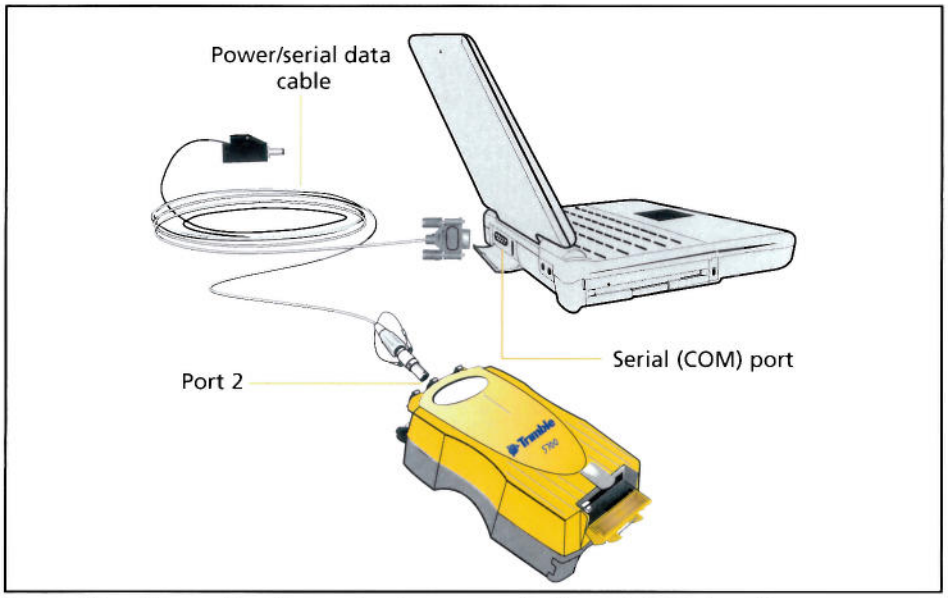


Figure 6.1 Connecting the receiver to a computer for serial data transfer

Use the USB cable to connect the receiver to the computer, as shown in Figure 6.2.

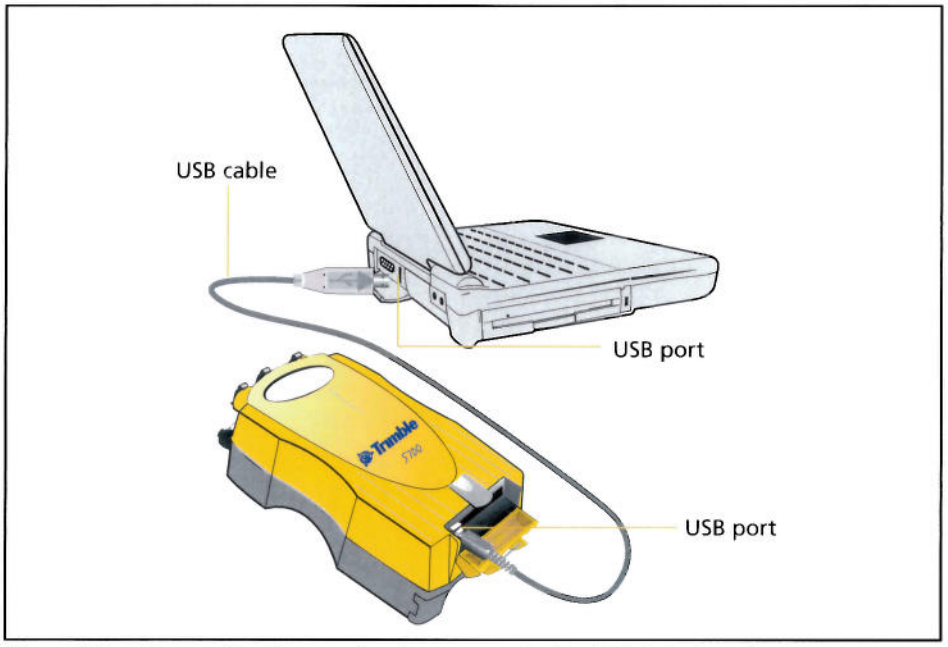


Figure 6.2 Connecting the receiver to a computer for USB data transfer

Note – *When the receiver is connected to a USB port on a computer, it is treated as a peripheral device of the computer. If the receiver is unplugged or turned off, a warning message appears on the computer.*

Transferring data

Transfer the data files to the computer using Trimble Business Center software or the Trimble Data Transfer utility. You can run the Data Transfer utility as a standalone program. For more information, refer to the *Trimble Business Center Help or the Data Transfer Help.*

Note – *When you connect to a receiver using Trimble Business Center software or in the Data Transfer utility, you must use a GPS Receiver (R/5000 Series) device definition. If you use a GPS Receiver (4000 Series) device definition, the software cannot establish communication with the receiver.*

When transfer is complete, the Data Transfer utility automatically converts the file to the DAT format. In doing so, the utility strips out any GLONASS data that was collected using a Trimble R7 GNSS receiver. If you use Trimble Business Center software to download your files, they remain in the native .T01 format, and GLONASS data is preserved.

Note – *A file in DAT format is approximately six times the size of the corresponding file in the receiver internal (.T01) format. Before transferring files using the Data Transfer utility, make sure that there is enough space on your computer.*

Transferring files from a CompactFlash card

In a receiver, all data is stored on an internal CompactFlash card. There are different ways to transfer files between the receiver and the office computer:

- Connect the receiver to the office computer and use the Trimble Business Center software to transfer files
- Remove the CompactFlash card from the receiver and connect it directly to your office computer, where it functions like a normal disk drive. Use Windows Explorer to transfer files.
- Connect the receiver to the office computer and use the Data Transfer utility to transfer files.

Transferring files using Trimble Business Center

Trimble Business Center can process the receiver raw data files (.T01). To transfer files, connect the computer directly to the receiver, or connect the CompactFlash card to the computer.

No conversions of the .T01 files are necessary. Any GPS or GLONASS data in the .T01 files is used in the processing of baselines.

Transferring files for processing in Trimble Geomatics Office software

Trimble Geomatics Office™ software cannot directly import the raw receiver files (.T01). They must be converted to the Trimble DAT file format for use.

CAUTION – The conversion of the raw receiver data (.T01) files into the Trimble DAT file format results in the loss of any Glonass data that was collected by a Trimble R7 GNSS receiver.

When you use the Data Transfer utility to transfer data files from the CompactFlash card while it is still inserted in the receiver, the Data Transfer utility converts the raw receiver data (.T01) files you select into the Trimble DAT file format.

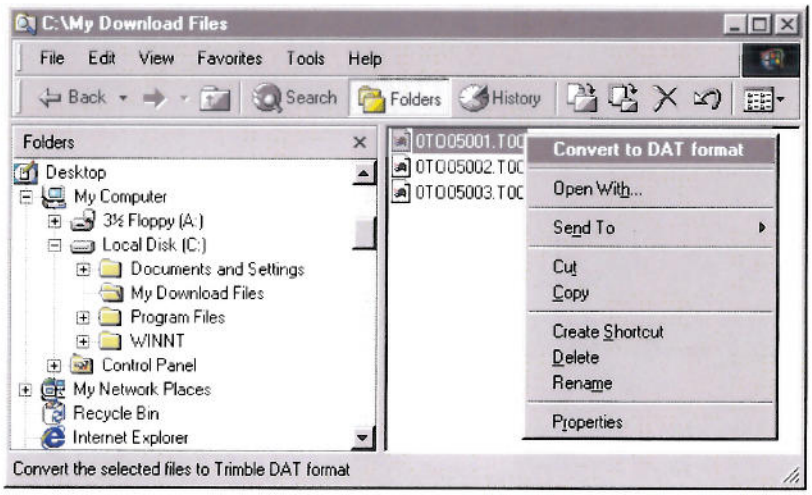
However, if you connect the CompactFlash card to your computer and then copy or move files to your computer, it treats the card like any other disk drive, and transfers the files without converting them. You need to convert these raw receiver files to DAT format files before you can use them on your office computer.

You can convert receiver data files using a Windows Explorer extension, which is installed on your computer when you install the Data Transfer utility.

Note – *Although this extension is only available if you have the Data Transfer utility installed, you do not have to run the Data Transfer utility to use it.*

To convert a .T01 file on your office computer into the DAT format:

1. On your office computer, open Windows Explorer and navigate to the location of the .T01 file.
2. Right-click the file, and select *Convert to DAT format* from the shortcut menu:



The *DAT File Conversion* dialog appears while the file is converted. When the dialog disappears, the file conversion is complete.

A new file with the same filename but a .dat extension appears in the same folder as the .T01 file.

Deleting files in the receiver

You can delete files stored in the receiver at any time. Do one of the following:

- Use the Data Transfer utility or the Trimble Business Center software.
- Use the controller.
- Turn on the receiver and then hold down P for 30 seconds. When you use this method, ***all*** data is deleted, and the CompactFlash card is reformatted.
- Use the GPS Configurator software.

Supported file types

Table 6.1 shows the file types that you can transfer to or from a receiver, and the software or utility that you must use to transfer each file type.

Table 6.1 Supported file types

File Type	Extensions	Transfer from receiver?	Transfer to receiver?	Software / utility
Ephemeris	.eph	Yes	No	Data Transfer or Trimble Business Center
Raw observations	.T01, .dat	Yes	No	Data Transfer or Trimble Business Center
Receiver firmware files	.elf	No	Yes	WinFlash
Application files	.cfg	Yes	Yes	GPS Configurator

Note – *The receiver supports more than 500 files on the CompactFlash card. Files stored on the compact flash must be 8.3 format. The receiver does not support extended file names.*

CHAPTER

7

Software Utilities

In this chapter:

- The GPS Configurator software
- The WinFlash utility

This chapter describes the software utilities that you can use with the receiver.

The GPS Configurator software

GPS Configurator is office software that configures selected Trimble receivers.

This software enables you to:

- edit and save configuration files to the receiver and the computer
- check current receiver settings and operation
- change receiver settings in real time

Installing the GPS Configurator software

A copy of the GPS Configurator software is included on the receiver CD.

1. Insert the disk into the CD drive on your office computer.
2. From the main menu, select *Install individual software packages.*
3. Select *Install GPS Configurator vX.XX.*
4. Follow the on-screen instructions.

Configuring the receiver using the GPS Configurator software

1. Connect Port 1 or 2 on the receiver to a serial (COM) port on the computer and then apply power.
2. To start the GPS Configurator software, click Start and then select *Programs / Trimble / GPS Configurator / GPS Configurator.*
3. In the *Device Type* dialog, select *Trimble 5700*.

   The software automatically establishes a connection with the receiver.
4. Make appropriate selections for your required receiver settings.

   For more information, refer to the *GPS Configurator Help.*
5. Click **Apply**.

   The settings in the GPS Configurator software are applied to the receiver.

The WinFlash utility

The WinFlash utility communicates with Trimble products to perform various functions including:

- installing software, firmware, and option upgrades
- running diagnostics (for example, retrieving configuration information)
- configuring radios

For more information, online help is also available when using the WinFlash utility.

Note – *The WinFlash utility runs on Windows 2000, XP, or Windows Vista® operating systems.*

Installing the WinFlash utility

Install the WinFlash utility from the receiver CD:

1. Insert the disk into the CD drive on your computer.
2. From the main menu, select *Install individual software packages.*
3. Select *Install WinFlash vX.XX with 5700 drivers and firmware* and then follow the on-screen instructions.

Alternatively, install the WinFlash utility from the Trimble website.

Upgrading firmware

Your receiver is supplied with the latest version of receiver firmware installed. If a later version becomes available, upgrade the firmware installed on your receiver.

The WinFlash utility guides you through the firmware upgrade process, as described below. For more information, refer to the *WinFlash Help*.

To upgrade the receiver firmware:

1. Start the WinFlash utility. The *Device Configuration* screen appears.
2. From the *Device type* list, select *5700* or *Trimble R7.*
3. From the *PC serial port* field, select the serial (COM) port on the computer that the receiver is connected to.
4. Click **Next**.

   The *Operation Selection* screen appears. The *Operations* list shows all of the supported operations for the selected device. A description of the selected operation is shown in the *Description* field.
5. Select *GPS software upgrade* and then click **Next**.

   The *GPS Software Selection* dialog appears. This screen prompts you to select the software that you want to install on the receiver.
6. Select the latest version from the *Available Software* list and then click **Next**.

   The *Settings Review* dialog appears. This screen prompts you to connect the receiver, suggests a connection method and then lists the receiver configuration and selected operation.
7. If all is correct, click **Finish**.

   Based on your selections, the *Software Upgrade* window appears and shows the status of the operation (for example, Establishing communication with the 5700. Please wait.).
8. Click **OK**.

   The *Software Upgrade* window appears again and states that the operation was completed successfully.
9. Click **Menu** to select another operation, or click **Exit** to quit WinFlash.

10. If you click **Exit**, another screen appears asking you to confirm that you want to quit. Click **OK**.

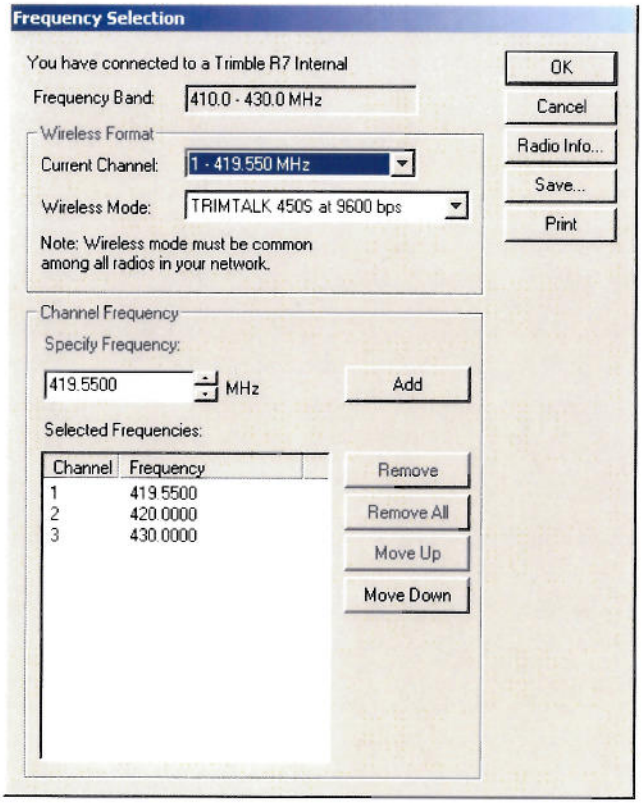
Adding frequencies for the 450 MHz internal radio

If your receiver has the optional internal radio installed, you can use the WinFlash utility to add receiving frequencies to the default list:

1. Start the WinFlash utility. The *Device Configuration* dialog appears.
2. From the *Device type* list, select the appropriate receiver name.
3. From the *PC serial port* field, select the serial (COM) port on the computer that the receiver is connected to.
4. Click **Next**.

   The *Operation Selection* screen appears. The *Operations* list shows all of the supported operations for the selected device. A description of the selected operation is shown in the *Description* field.
5. Select Configure Radio and then click **Next**.

   The *Frequency Selection* dialog appears:



6. In the *Wireless Format* group, select the appropriate channel and wireless mode. The *Wireless Mode* must be the same for all radios in your network.
7. In the *Specify Frequency* field, enter the frequency you require.
8. Click **Add**. The new frequency appears in the *Selected Frequencies* list.

Note – *The frequencies that you program must conform to the channel spacing and minimum tuning requirements for the radio. To view this information, click* ***Radio Info****. You may select either 12.5 or 25 kHz channel spacing. All radios in your network must use the same channel spacing.*

9. When you configure all the frequencies you require, click **OK**. The WinFlash utility updates the receiver radio frequencies and then restarts the receiver.

CHAPTER

8

Specifications

In this chapter:

- Physical specifications
- Positioning specifications
- Technical specifications

This chapter lists the receiver specifications. Where specifications apply to only one receiver model, this is clearly indicated.

Physical specifications

Feature	Specification
Size	13.5 cm W x 8.5 cm H x 24 cm L (5.3 in. W x 3.4 in. H x 9.5 in. L)
Weight (with 2 batteries inserted)	1.5 kg (3.1 lb)
Operating times (with two 2.4 Ah batteries) (at 20 °C)	RTK with Internal Radio: 6-8 hours Post Processed: > 10 hours
Power input	10.5-28 V DC , with over-voltage protection
Operating temperature	–40 °C to +65 °C (–40 °F to +149 °F)
Storage temperature	–40 °C to +80 °C (–40 °F to +176 °F)
Humidity	100% condensing, unit fully sealed
Casing	Tough, lightweight, fully sealed magnesium alloy
Water/dustproof	IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)

The receiver will operate normally to -40 °C; internal batteries are rated to -20 °C. The temperature rating of the receiver applies only when all doors on the receiver are closed.

Positioning specifications

Feature	Specification
Code differential GPS positioning[a]	
Horizontal	±0.25 m + 1ppm RMS
Vertical	±0.50 m + 1ppm RMS
WAAS differential positioning accuracy[b]	typically <5 m 3DRMS
Static and FastStatic GPS surveying[a]	
Horizontal	±5 mm + 0.5 ppm RMS
Vertical	±5 mm + 1 ppm RMS
Kinematic surveying[a]	
Horizontal	±10 mm + 1 ppm RMS
Vertical	±20 mm + 1 ppm RMS

[a] Accuracy and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. Always follow recommended survey practices.

[b] Depends on WAAS/EGNOS system performance.

Technical specifications

Feature	Specification
Tracking	
Trimble R7 GNSS receiver	72 Channels GPS L1 C/A Code, L2C, L1/L2/L5 Full Cycle Carrier, GLONASS L1 C/A Code, L1 P Code, L2 P Code, L1/L2 Full Cycle Carrier, 4 additional channels for SBAS WAAS/EGNOS support Fully operational during P-code encryption
5700 GPS receiver	24 Channels GPS L1 C/A Code, L1/L2 Full Cycle Carrier 2 additional channels for SBAS WAAS/EGNOS support Fully operational during P-code encryption
Signal processing	Advanced Trimble Maxwell™ Custom Survey GNSS chip Very low-noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth Multipath suppression
Initialization	Automatic while moving or static
Initialization time[a]	Typically, <10 seconds (Trimble R7 GNSS) receiver Typically, <20 seconds (5700 receiver)
Initialization reliability[b].	Typically, >99.9%
Communications	Three RS-232 serial ports (Port 1, Port 2, and Port 3) Baud rates up to 115,200 bps RTS/CTS flow control negotiation supported on Port 3 only One USB port (download only)
Configuration	Via user-definable application files or GPS Configurator
Output formats	NMEA-0183: AVR; GGA; GSA; GST; GSV; PTNL,GGK; PTNL,GGK_SYNC; HDT; PTNL,PJK; PTNL,PJT; ROT PTNL,VGK; VHD; VTG; ZDA GSOF (Trimble Binary Streamed Output) 1PPS RT17

[a] May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry.
[b] May be affected by atmospheric conditions, signal multipath, and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.

CHAPTER

9

Default Settings

In this chapter:

- Default settings
- Resetting to factory defaults
- Default behavior
- Power up settings

All receiver settings are stored in application files. The default application file, Default.cfg, is stored permanently in the receiver, and contains the factory default settings for the receiver. Whenever the receiver is reset to its factory defaults, the current settings (stored in the current application file, current.cfg) are reset to the values in the default application file.

You cannot modify the default application file. however, if there is a power up application file (Power_up.cfg) in the receiver, the settings in this file can be applied immediately after the default application file, overriding the factory defaults.

For more information, see Application files, page 46.

Default settings

These settings are defined in the default application file.

Function		Factory Default
SV Enable		All SVs enabled
General Controls:	Elevation mask	13°
	PDOP mask	7
	RTK positioning mode	Low Latency
	Motion	Kinematic
Power Output 3		Disabled
1PPS time tags		Off
ASCII time tags		Off
Serial Port 1:	Baud rate	38400
	Format	8-None-1
	Flow control	None
Serial Port 2:	Baud rate	38400
	Format	8-None-1
Serial Port 3:	Baud rate	38400
	Format	8-None-1
	Flow control	None
Input Setup:	Station	Any
NMEA/ASCII (all messages)		All Ports Off
Streamed output		All Types Off Offset = 00
RT17/Binary		All Ports Off
CMR output		[Static] CMR: cref ID 0000
RTCM output		RTCM: Type 1 ID 0000
Reference position:	Latitude	0°
	Longitude	0°
	Altitude	0.00 m HAE
Antenna:	Type	Unknown external
	Height (true vertical)	0.00 m
	Group	All
	Measurement method	Bottom of antenna mount
Logging rate		15 sec
Position rate		5 min
Measurement rate		10 Hz

Resetting to factory defaults

To reset the receiver to its factory defaults, do one of the following:

- On the receiver, press and hold down P for 15 seconds.
- In the GPS Configurator software, select *Connect to Receiver* and then click **Reset receiver** in the *General* tab.

Default behavior

The factory defaults are applied whenever you start the receiver. If a power up file is present in the receiver, its settings are applied immediately after the default settings, so you can use a power up file to define your own set of defaults.

When you turn the receiver on and ...	then logging settings are ...	and logging ...
it is the first time that the receiver has been used	the factory defaults	does not begin automatically
you have reset the receiver to its factory defaults	the factory defaults, or those in the power up file[a]	does not begin automatically
you have performed a full reset	the factory defaults, because resetting deletes any power up file	does not begin automatically

[a]A factory default setting is used only if the setting is not defined in the power up file.

Power up settings

When you turn the receiver off, any changes that you have made to logging settings are lost and these settings are returned to the factory defaults. Other settings remain as defined in the current file. The next time you turn on the receiver, the receiver checks for a power up file and, if one is present, applies the settings in this file.

When you use P to turn the receiver off then on again and ...	then logging settings are ...	and all other settings are ...
you changed the receiver settings by applying an application file	the factory defaults	the last settings used
you changed the receiver settings using configuration software	the factory defaults	the last settings used
there is a power up application file in the receiver	the factory defaults, or those in the power up file[a]	the last settings used, or those in the power up file[a]

[a]A factory default setting is used only if the setting is not defined in the power up file.

Logging after power loss

If the receiver loses power unexpectedly, when power is restored the receiver tries to return to the state it was in immediately before the power loss. The receiver does not reset itself to defaults or apply any power up settings. If the receiver was logging when power was lost unexpectedly, it resumes logging when power is restored.

However, when you turn off the receiver using P, the receiver behaves as if you pressed D to stop logging before you pressed P. In this case, when power is restored normally, logging does not begin until you start it manually.

When the receiver is logging data and then loses power ...	then when power is restored, data logging ...	and logging settings are ...	and all other settings are ...
unexpectedly	resumes automatically	the last settings used	the last settings used
when you press P	does not resume	the factory defaults	the last settings used

Disabling logging

To disable logging, you can set the receiver's data logging and position logging rates to Off. However, if you press D while logging is disabled, the receiver will still log data, using the default logging settings.

When you have disabled logging ...	then if you press D to start logging, logging settings are ...
using the Trimble Survey Controller or GPS Configurator software	the factory defaults
in the power up application file	the factory defaults

Application files

You can use application files to change the settings in the receiver. Sending an application file to the receiver does not necessarily apply the file's settings; you can apply a file's settings at any time after sending it to the receiver. You can also define timed application files. A timed application file contains receiver settings, but also includes a date and time when it is automatically activated.

If there is a timed application file on the receiver, the receiver automatically applies the file's settings and begins logging (if logging settings are included in the file) at the specified time. If the receiver is in Sleep mode, it wakes up five minutes before the start time of the timed application file, and then begins logging, if required, at the specified start time.

When you send an application file to the receiver and ...	then the receiver settings are changed ...
you apply the file's settings immediately	as soon as you send the file to the receiver

When you send an application file to the receiver and ...	then the receiver settings are changed ...
you apply the file later	as soon as you apply the file
it is a timed application file	at the specified activation time

CHAPTER

10

Cables and Connectors

In this chapter:

- Port 1, 2, and 3 connectors
- Power/serial data cable
- Event marker/1PPS cable
- GPS antennas and cables

This chapter describes the pinouts for the receiver standard and optional cables. This information can be used to build special cables for connecting the receiver to devices and instruments not supported by the standard and optional cables.

Port 1, 2, and 3 connectors

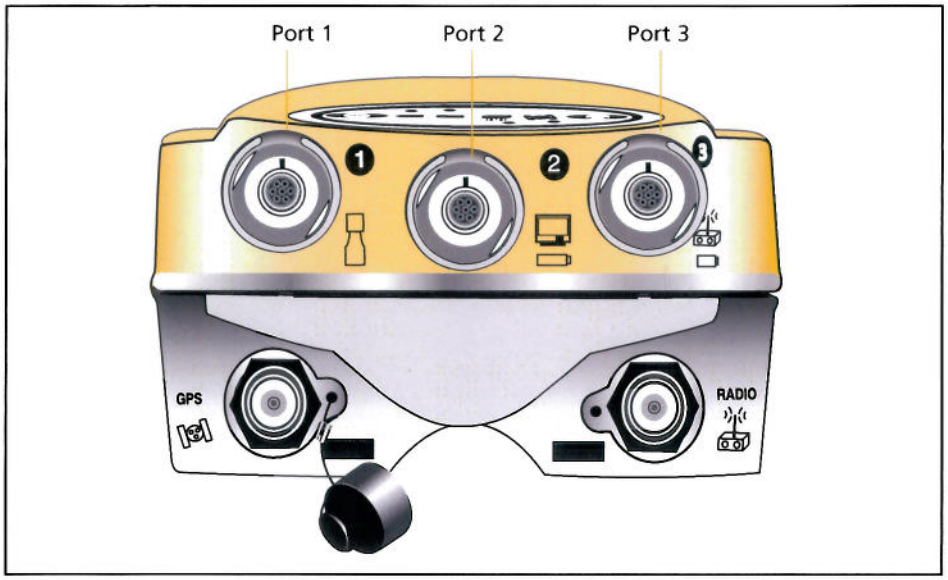


Figure 10.1 Receiver serial ports

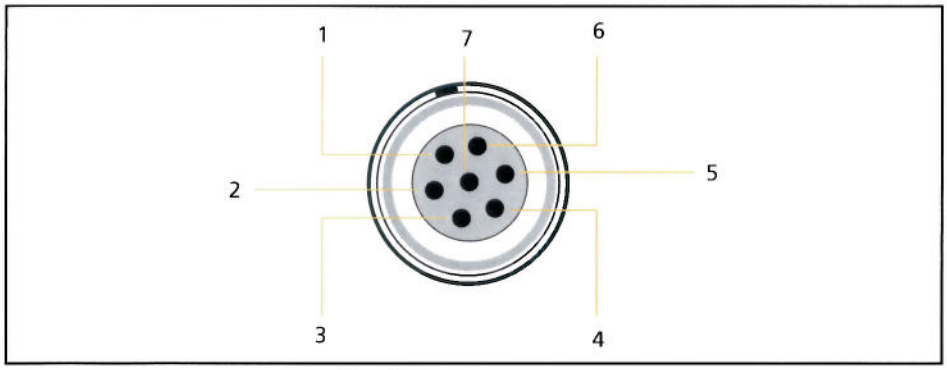


Figure 10.2 Pinout connectors for all ports

Table 10.1 receiver port pinout functions

Pin	Pinout function		
	Port 1 (Trimble controller, event, or computer)	**Port 2 (Power in, computer, PPS, or event)**	**Port 3 (External radio or power in)**
1	Signal GND	Signal GND	Signal GND
2	GND	GND	GND
3	TX data out (TXD1)	TX data out (TXD2)	TX data out (TXD3)
4	RTS1	1PPS	RTS3
5	CTS1/Event 2	Event 1	CTS3
6	Power Out (+)	Power In (+)	Power In/Out (+)
7	Serial data in (RXD1)	Serial data in (RXD2)	Serial data in (RXD3)

Power/serial data cable

The power/serial data cable (P/N 59044) is supplied with the receiver.

Table 10.2 Power/serial data cable pinouts

Lemo 0-shell connector 7 Pin		Direction	DE9-F connector 7 Conductors			Power lead 2 Conductors	
Pin	**Function**		**Pin**	**Color**	**Function**	**Color**	**Function**
1	Signal ground	↔	5	Brown	Signal ground		
2	GND	→				Black	V-OUT
3	TXD	→	2	Orange	TXD		
4	RTS/TXD	→	8	Blue	RTS		
5	CTS/RXD	←	7	Green	CTS		
6	PWR	←				Red	Power IN (+)
7	RXD	←	3	Yellow	TXD		

Note – *Table 10.2 assumes that the cable is attached to the connector labeled Port 1 or Port 3.*

Event marker/1PPS cable

The event marker/1PPS cable shown in Figure 10.3 provides a breakout box with two BNC (female) connectors for 1PPS input and event marker output.

Connect a device that accepts 1PPS output pulses to the BNC connector labeled 1PPS on the breakout box. Connect a device that outputs event marker pulses to the receiver, such as a photogrammetric camera, to the BNC connector labeled Event Marker on the breakout box.

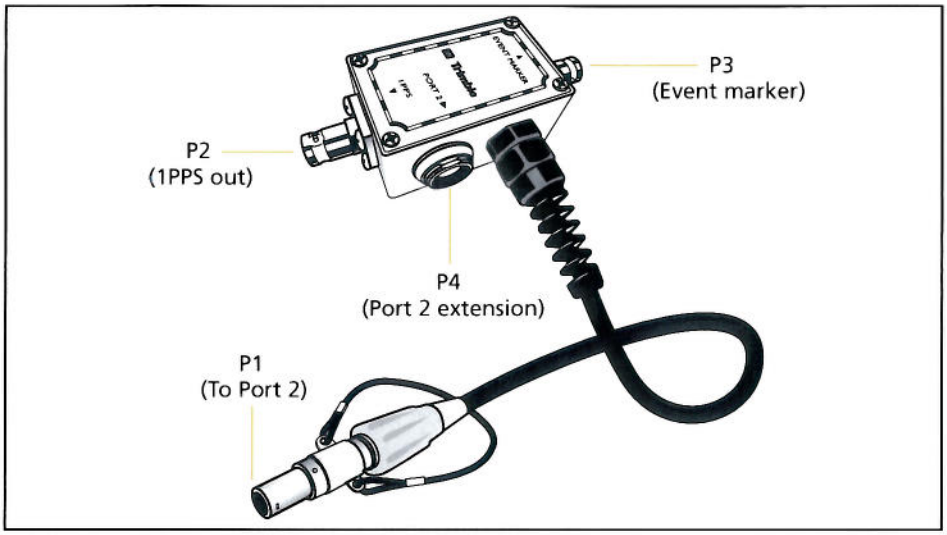


Figure 10.3 Event marker/1PPS cable

In addition, the breakout box includes a Lemo 7-pin connector to extend serial communications and/or power on Port 2. Because the BNC connectors are used to service the event marker and 1PPS features, pins 4 (1PPS) and 5 (Event Marker) are inactive on the Lemo connector.

For Port 2 pinouts, see Port 1, 2, and 3 connectors, page 74. For more information on 1PPS input and event marker output, see Chapter 11, Event Marker Input and 1PPS Output.

Table 10.3 gives pinout information for the event marker/1PPS cable, which is supplied with the receiver. The event marker/1PPS cable is only used with the receiver connectors labeled Port 1 (for event marker output) and Port 2.

Table 10.3 Event marker/1PPS cable pinouts

P1: Lemo 7-Pin Port 2 receiver		**Direction**	**P2: BNC-F connector (1PPS)**	**P3: BNC-F connector (Event marker)**	**P4: Lemo 7s Port 2 extension**	
Pin	**receiver function**		**Pin**	**Pin**	**Pin**	**Function**
1	Signal ground	←			1	Signal ground
2	GND	→	GND	GND	2	GND
3	Serial data out (TXD2)	←			3	Serial data in (TXD2)
4	1PPS	←	Center pin		4	No Connect
5	Event Marker	↔		Center pin	5	No Connect
6	Power IN (+)	→			6	Power IN (+)
7	Serial data in (RXD2)	←			7	Serial data out (RXD2)

GPS antennas and cables

The antenna that a receiver uses to collect satellite signals is sometimes called a GPS antenna to distinguish it from a radio antenna. Radio antennas are used for communication between receivers and external networks or systems.

Note – *Choke Ring antennas or older models, such as Micro-Centered L1/L2, have different power requirements. The receiver can adjust the antenna power output when you designate the appropriate antenna in the GPS Configurator software. For more information, see* *Antennas, page 31*.

Connect the receiver to its GPS antenna using the yellow TNC connector. Use a coaxial cable with a right-angle TNC plug at the antenna end.

If the antenna cable length is ...	use ...
up to 15 meters (45 feet)	RG-58 cable
up to 30 meters (100 feet)	RG-214 cable
over 30 meters (100 feet)	one of the following: • in-line amplifier • semi-rigid coaxial cable • a low-loss cable assembly

CHAPTER

11

Event Marker Input and 1PPS Output

In this chapter:

- Event marker input
- 1PPS output

The receiver can accept event marker input on Port 1 and port 2, and can generate 1PPS output on Port 2.

Event marker input

Use event marker input to log a precise GPS time tag whenever an externally generated pulse is received, such as one generated at the time of the shutter closing from a photogrammetric camera.

The event is triggered when the source pulse voltage transitions between 1.0 V DC and 2.0 V DC in less than 100 nsec. Trimble recommends that you use TTL level inputs. You can configure the receiver to recognize either a positive (rising) or negative (falling) voltage as the leading edge of a pulse. The accuracy of the associated time tag recorded for an event is determined by the GPS accuracy (typically less than 1 µsec.).

The receiver records each event in the current data file. This record includes the port on which the event was received.

Enabling and configuring event marker input

To enable or configure the event marker input function, you need the GPS Configurator software.

In real time

You can use the GPS Configurator software to configure a Trimble GPS receiver connected to your office computer. For more information, see The GPS Configurator software, page 58, or refer to the *GPS Configurator Help*.

To enable event marker input:

1. Connect the computer to the receiver.
2. Press P to turn on the receiver.
3. To start the GPS Configurator software, click Start and then select *Programs / Trimble / GPS Configurator / GPS Configurator*. The *GPS Configurator* dialog appears and the software automatically connects to the receiver.
4. In the *General* tab, select the *Event marker* check box.
5. Select the appropriate option, Positive slope or Negative slope, depending on the type of pulse the external device uses.
6. Click **Apply**.

   The GPS Configurator software sends the new configuration information to the receiver, and the receiver starts to accept event marker input.
7. Click **OK** to exit the GPS Configurator software.

   The software disconnects from the receiver.

1PPS output

The receiver can output a one pulse per second (1PPS) time strobe with an associated ASCII time tag output. The pulse is output through port 2 of the receiver using the event marker/1PPS cable.

1PPS pulse definition

The leading edge of the pulse coincides with the beginning of each UTC second, as shown in Figure 11.1. The pulse is driven by an RS-422 driver between nominal levels of 0 V and 4 V. The leading edge is positive, rising from 0 V to 4 V.

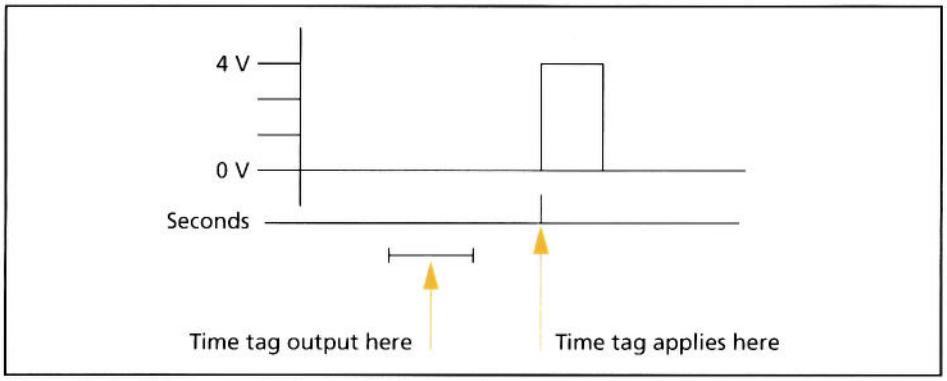


Figure 11.1 Time tag relation to 1PPS wave form

The pulse is approximately 8 µsec wide, with rise and fall times of about 100 nsec. Resolution is approximately 40 nsec, but several external factors limit accuracy to approximately ±1 µsec:

- Position errors, especially with user-entered reference. Each meter of error can result in 3 nsec of error in the 1PPS pulse.
- Antenna cable length. Each meter of cable adds a delay of about 2 nsec to satellite signals, and a corresponding delay in the 1PPS pulse.

ASCII time tag definition

Each time tag is output about 0.5 second before the corresponding pulse, as shown in Figure 11.1. Time tags are in ASCII format on a user-selected serial port. The format of a time tag is:

UTC yy.mm.dd hh:mm:ss ab

Where:

- *UTC* is fixed text.
- *yy.mm.dd* is the year, month, and date.
- *hh:mm:ss* is the hour (on a 24-hour clock), minute, and second. The time is in UTC, not GPS time.

- *a* is the position-fix type:

  1 = 2D Position Fix for E,N only
  2 = 3D Position Fix
  3 = Single SV Clock-only fix
  4 = Automatic Mode
  5 = Reference Station Position
  6 = Two-Dimensional with Fixed Clock
  7 = Overdetermined solution for Clock-only

- *b* is the number of satellites being tracked: 1 to 9, ":" (for 10), ";" (for 11), or "<" (for 12).

- Each time tag is terminated by a *carriage return, line feed* sequence.

A typical printout looks like this:

UTC 93.12.21 20:21:16 56
UTC 93.12.21 20:21:17 56
UTC 93.12.21 20:21:18 56

If the fields "*a*" and "*b*" appear as "*??*", the time is based on the receiver clock because the receiver is not tracking satellites. The receiver clock is less accurate than time readings extracted from satellite signals.

Enabling and configuring 1PPS output in real time

To enable or configure the 1PPS output function, you need the GPS Configurator software. You can use the GPS Configurator software to configure a Trimble GPS receiver connected to your office computer. For more information, see The GPS Configurator software, page 58, or refer to the *GPS Configurator Help*.

1. Connect the computer to the receiver.
2. Turn on the receiver.
3. To start the GPS Configurator software, click **Start** and then select *Programs / Trimble / GPS Configurator / GPS Configurator*. The *GPS Configurator* dialog appears and the software automatically connects to the receiver.
4. Select the *Serial outputs* tab.
5. Select the *1PPS (Port 2 only)* check box.
6. If you want ASCII time tags enabled, select the check box and choose an output port.
7. Click **Apply**.

   The GPS Configurator software sends the new configuration information to the receiver, and the receiver starts to generate 1PPS output on Port 2.
8. Click **OK** to exit the GPS Configurator software.

   The software disconnects from the receiver.

APPENDIX

A

NMEA-0183 Output

In this appendix:

- NMEA-0183 Outputs
- Common Message Elements
- NMEA Messages

This appendix describes the formats of the subset of NMEA-0183 messages that are available for output by the receiver.

For a copy of the NMEA-0183 Standard, go to the National Marine Electronics Association website at www.nmea.org.

NMEA-0183 Outputs

When NMEA-0183 output is enabled, a subset of NMEA-0183 messages can be output to external instruments and equipment connected to the Trimble receiver serial ports. These NMEA-0183 messages let external devices use selected data collected or computed by the receiver.

All messages conform to the NMEA-0183 version 3.01 format. All begin with $ and end with a carriage return and a line feed. Data fields follow comma (,) delimiters and are variable in length. Null fields still follow comma (,) delimiters but contain no information.

An asterisk (*) delimiter and checksum value follow the last field of data contained in an NMEA-0183 message. The checksum is the 8-bit exclusive *OR* of all characters in the message, including the commas between fields, but not including the $ and asterisk delimiters. The hexadecimal result is converted to two ASCII characters (0–9, A–F). The most significant character appears first.

The following table summarizes the set of NMEA messages supported by the receiver, and shows the page where detailed information about each message can be found.

Message	Function	Page
AVR	Time, yaw, tilt, range, mode, PDOP, and number of SVs for Moving Baseline RTK	86
GGA	Time, position, and fix related data	86
GSA	GNSS DOP and active satellites	87
GST	Position error statistics	88
GSV	Number of SVs in view, PRN, elevation, azimuth, and SNR	88
HDT	Heading from True North	89
PTNL,GGK	Time, position, position type and DOP values	89
PTNL,GGK_SYNC	Time, synchronized position, position type and DOP values	90
PTNL,PJK	Local coordinate position output	91
PTNL,PJT	Projection type	91
PTNL,VGK	Time, locator vector, type and DOP values	92
PTNL,VHD	Heading Information	92
RMC	Position, Velocity, and Time	93
ROT	Rate of turn	93
VTG	Actual track made good and speed over ground	94
ZDA	UTC day, month, and year, and local time zone offset	94

To enable or disable the output of individual NMEA messages, do one of the following:

- Create an application file in the GPS Configurator software that contains NMEA output settings and then send the file to the receiver.
- Add NMEA outputs in the *Serial outputs* tab of the GPS Configurator software and then apply the settings.

Common Message Elements

Each message contains:

- A message ID consisting of *$GP* followed by the message type. For example, the message ID of the GGA message is *$GPGGA*.
- A comma
- A number of fields, depending on the message type, separated by commas
- An asterisk
- A checksum value

Below is an example of a simple message with a message ID ($GPGGA), followed by 13 fields and a checksum value:

$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,2,6,1.2,18.893,M,-25.669,M,2.0,0031*4F

Message values

The following values can be found in NMEA messages that the receiver generates.

Latitude and longitude

Latitude is represented as *ddmm.mmmm* and longitude is represented as *dddmm.mmmm*, where:

- dd or ddd is degrees
- mm.mm*mm* is minutes and decimal fractions of minutes

Direction

Direction (north, south, east, or west) is represented by a single character: *N*, *S*, *E*, or *W*.

Time

Time values are presented in Universal Time Coordinated (UTC) and are represented as *hhmmss.cc*, where:

- *hh* is hours, from 00 to 23
- *mm* is minutes
- *ss* is seconds
- *cc* is hundredths of seconds

NMEA Messages

When NMEA-0183 output is enabled, the following messages can be generated.

AVR Time, Yaw, Tilt, Range for Moving Baseline RTK

The AVR message string is shown below, and Table A.1 describes the message fields.

$PTNL,AVR,181059.6,+149.4688,Yaw,+0.0134,Tilt,,,60.191,3,2.5,6*00

Table A.1 AVR message fields

Field	Meaning
1	UTC of vector fix
2	Yaw angle in degrees
3	Yaw
4	Tilt angle in degrees
5	Tilt
6	Reserved
7	Reserved
8	Range in meters
9	Quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential carrier phase solution RTK (Float) 3: Differential carrier phase solution RTK (Fix) 4: Differential code-based solution, DGPS
10	PDOP
11	Number of satellites used in solution

GGA Time, Position, and Fix Related Data

An example of the GGA message string is shown below. Table A.2 describes the message fields.

$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,
2,6,1.2,18.893,M,-25.669,M,2.0,0031*4F

Table A.2 GGA message fields

Field	Meaning
1	UTC of position fix
2	Latitude
3	Direction of latitude: N: North S: South
4	Longitude

Table A.2 GGA message fields (continued)

Field	Meaning
5	Direction of longitude: E: East W: West
6	GPS Quality indicator: 0: Fix not valid 1: GPS fix 2: Differential GPS fix 4: Real Time Kinematic, fixed integers 5: Real Time Kinematic, float integers
7	Number of SVs in use, range from 00 to 12
8	HDOP
9	Orthometric height (MSL reference)
10	M: unit of measure for height is meters
11	Geoid separation
12	M: geoid separation is measured in meters
13	Age of differential GPS data record, Type 1 or Type 9. Null field when DGPS is not used.
14	Reference station ID, ranging from 0000 to 1023. A null field when any reference station ID is selected and no corrections are received.

GSA GNSS DOP and active satellites

An example of the GSA message string is shown below. Table A.3 describes the message fields.

$GPGSA,<1>,<2>,<3>,<3>,,,,,<3>,<3>,<3>,<4>,<5>,
<6>*<7><CR><LF>

Table A.3 GSA message fields

Field	Meaning
1	Mode 1, M = manual, A = automatic
2	Mode 2, Fix type, 1 = not available, 2 = 2D, 3 = 3D
3	PRN number, 01 to 32, of satellite used in solution, up to 12 transmitted
4	PDOP-Position dilution of precision, 0.5 to 99.9
5	HDOP-Horizontal dilution of precision, 0.5 to 99.9
6	VDOP-Vertical dilution of precision, 0.5 to 99.9
7	Checksum

GST Position Error Statistics

An example of the GST message string is shown below. Table A.4 describes the message fields.

$GPGST,172814.0,0.006,0.023,0.020,273.6,
0.023,0.020,0.031*6A

Table A.4 GST message fields

Field	Meaning
1	UTC of position fix
2	RMS value of the pseudorange residuals (includes carrier phase residuals during periods of RTK(float) and RTK(fixed) processing)
3	Error ellipse semi-major axis 1 sigma error, in meters
4	Error ellipse semi-minor axis 1 sigma error, in meters
5	Error ellipse orientation, degrees from true north
6	Latitude 1 sigma error, in meters
7	Longitude 1 sigma error, in meters
8	Height 1 sigma error, in meters

GSV Satellite Information

The GSV message string identifies the number of SVs in view, the PRN numbers, elevations, azimuths, and SNR values. An example of the GSV message string is shown below. Table A.5 describes the message fields.

$GPGSV,4,1,13,02,02,213,,03,-3,000,,
11,00,121,,14,13,172,05*67

Table A.5 GSV message fields

Field	Meaning
1	Total number of messages of this type in this cycle
2	Message number
3	Total number of SVs visible
4	SV PRN number
5	Elevation, in degrees, 90° maximum
6	Azimuth, degrees from True North, 000° to 359°
7	SNR, 00–99 dB (null when not tracking)
8–11	Information about second SV, same format as fields 4–7
12–15	Information about third SV, same format as fields 4–7
16–19	Information about fourth SV, same format as fields 4–7

HDT Heading from True North

The HDT string is shown below, and Table A.6 describes the message fields.

$GPHDT,123.456,T*00

Table A.6 Heading from true north fields

Field	Meaning
1	Heading in degrees
2	T: Indicates heading relative to True North

PTNL,GGK Time, Position, Position Type, DOP

An example of the PTNL,GGK message string is shown below. Table A.7 describes the message fields.

$PTNL,GGK,172814.00,071296,
3723.46587704,N,12202.26957864,W,
3,06,1.7,EHT-6.777,M*48

Table A.7 PTNL,GGK message fields

Field	Meaning
1	UTC of position fix
2	Date
3	Latitude
4	Direction of latitude: N: North S: South
5	Longitude
6	Direction of Longitude: E: East W: West
7	GPS Quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential, floating carrier phase integer-based solution, RTK(float) 3: Differential, fixed carrier phase integer-based solution, RTK(fixed) 4: Differential, code phase only solution (DGPS)
8	Number of satellites in fix
9	DOP of fix
10	Ellipsoidal height of fix
11	M: ellipsoidal height is measured in meters

Note – *The PTNL,GGK message is longer than the NMEA-0183 standard of 80 characters.*

PTNL,GGK_SYNC

Time, Synchronized Position, Position Type, DOP

The PTNL,GGK_SYNC message has the same format as the PTNL,GGK message, but outputs Synchronized 1 Hz positions even in Low Latency mode. An example of the PTNL,GGK_SYNC message string is shown below. Table A.8 describes the message fields.

$PTNL,GGK_SYNC,172814.00,071296,
3723.46587704,N,12202.26957864,W,
3,06,1.7,EHT-6.777,M*48

Table A.8 PTNL,GGK_SYNC message fields

Field	Meaning
1	UTC of position fix
2	Date
3	Latitude
4	Direction of latitude: N: North S: South
5	Longitude
6	Direction of Longitude: E: East W: West
7	GPS Quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential, floating carrier phase integer-based solution, RTK(float) 3: Differential, fixed carrier phase integer-based solution, RTK(fixed) 4: Differential, code phase only solution (DGPS)
8	Number of satellites in fix
9	DOP of fix
10	Ellipsoidal height of fix
11	M: ellipsoidal height is measured in meters

Note – *The PTNL,GGK_SYNC message is longer than the NMEA-0183 standard of 80 characters.*

PTNL,PJK Local Coordinate Position Output

An example of the PTNL,PJK message string is shown below. Table A.9 describes the message fields.

$PTNL,PJK,010717.00,081796,
+732646.511,N,+1731051.091,E,
1,05,2.7,EHT-28.345,M*7C

Table A.9 PTNL,PJK message fields

Field	Meaning
1	UTC of position fix
2	Date
3	Northing, in meters
4	Direction of Northing will always be N (North)
5	Easting, in meters
6	Direction of Easting will always be E (East)
7	GPS Quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential, floating carrier phase integer-based solution, RTK (float) 3: Differential, fixed carrier integer-based solution, RTK (fixed) 4: Differential, code phase only solution (DGPS)
8	Number of satellites in fix
9	DOP of fix
10	Ellipsoidal height of fix
11	M: ellipsoidal height is measured in meters

Note – *The PTNL,PJK message is longer than the NMEA-0183 standard of 80 characters.*

PTNL,PJT Projection Type

An example of the PTNL,PJT message string is shown below. Table A.10 describes the message fields.

$PTNL,PJT,NAD83(Conus),California Zone 4 0404,*51

Table A.10 PTNL,PJT message fields

Field	Meaning
1	Coordinate system name (can include multiple words)
2	Projection name (can include multiple coordinates)

PTNL,VGK

Vector Information

An example of the PTNL,VGK message string is shown below. Table A.11 describes the message fields.

$PTNL,VGK,160159.00,010997,-0000.161,
00009.985,-0000.002,3,07,1,4,M*0B

Table A.11 PTNL,VGK message fields

Field	Meaning
1	UTC of vector in hhmmss.ss format
2	Date in mmddyy format
3	East component of vector, in meters
4	North component of vector, in meters
5	Up component of vector, in meters
6	GPS quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential carrier phase solution RTK(float) 3: Differential carrier phase solution RTK(fix) 4: Differential code-based solution, DGPS
7	Number of satellites if fix solution
8	DOP of fix
9	M: Vector components are in meters

PTNL,VHD

Heading Information

An example of the PTNL,VHD message string is shown below. Table A.12 describes the message fields.

$PTNL,VHD,030556.00,093098,187.718,
-22.138,-76.929,-5.015,0.033,0.006,
3,07,2.4,M*22

Table A.12 PTNL,VHD message fields

Field	Meaning
1	UTC of position, in *hhmmss.ss,ddmmyy* format
2	Date in mmddyy format
3	Azimuth
4	ΔAzimuth/ΔTime
5	Vertical Angle
6	ΔVertical/ΔTime
7	Range
8	ΔRange/ΔTime

Table A.12 PTNL,VHD message fields (continued)

Field	Meaning
9	Quality indicator: 0: Fix not available or invalid 1: Autonomous GPS fix 2: Differential carrier phase solution RTK(float) 3: Differential carrier phase solution RTK(fix) 4: Differential code-based solution, DGPS
10	Number of satellites used in solution
11	PDOP

RMC Position, Velocity, and Time

The RMC string is shown below, and Table A.13 describes the message fields.

$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A

Table A.13 GPRMC message fields

Field	Meaning
1	UTC of position fix
2	Status A=active or V=void
3	Latitude
4	Longitude
5	Speed over the ground in knots
6	Track angle in degrees (True)
7	Date
8	Magnetic variation
9	The checksum data, always begins with *

ROT Rate of Turn

The ROT string is shown below, and Table A.14 describes the message fields.

$GPROT,35.6,A*4E

Table A.14 ROT message fields

Field	Meaning
1	Rate of turn, degrees/minutes, "–" indicates bow turns to port
2	A: Valid data V: Invalid data

VTG Actual Track Made Good Over and Speed Over Ground

An example of the VTG message string is shown below. Table A.15 describes the message fields.

$GPVTG,,T,,M,0.00,N,0.00,K*4E

Table A.15 VTG message fields

Field	Meaning
1	Track made good (degrees true)
2	T: track made good is relative to true north
3	Track made good (degrees magnetic)
4	M: track made good is relative to magnetic north
5	Speed, in knots
6	N: speed is measured in knots
7	Speed over ground in kilometers/hour (kph)
8	K: speed over ground is measured in kph

ZDA UTC Day, Month, And Year, and Local Time Zone Offset

An example of the ZDA message string is shown below. Table A.16 describes the message fields.

$GPZDA,172809,12,07,1996,00,00*45

Table A.16 ZDA message fields

Field	Meaning
1	UTC
2	Day, ranging between 01 and 31
3	Month, ranging between 01 and 12
4	Year
5	Local time zone offset from GMT, ranging from 00 to ±13 hours
6	Local time zone offset from GMT, ranging from 00 to 59 minutes

Fields 5 and 6 together yield the total offset. For example, if field 5 is –5 and field 6 is +15, local time is 5 hours and 15 minutes earlier than GMT.

APPENDIX

B

RTCM Output

In this appendix:

- Generated messages
- Message scheduling

Generated messages

Table B.1 shows the messages that are generated when you select a specific RTCM version. The messages in the table are in the same order as they appear in the GPS Configurator software. For the details of the contents of individual messages, refer to the RTCM documentation.

Table B.1 RTCM output

Selection	Message								
Version 2	1	3				22			59
USCG 9-3		3	9-3						
RTCM/RTK 2.2+2.3	1	3		18	19	22	23	24	59
RTK Only 2.2+2.3		3		18	19	22	23	24	59
RTCM/RTK 2.3	1			18	19		23	24	
RTK Only 2.3				18	19	22			
RTCM/RTK 2.2	1	3		18	19	22			59
RTK Only 2.2		3		18	19	22			59
RTCM/RTK 2.1	1	3		18	19	22			59
RTK Only 2.1		3		18	19	22			59
RTCM/RTK 3.00						1004	1006	1008	1013

Message scheduling

Table B.2 describes the frequency at which messages are generated when they are enabled in a base receiver.

Table B.2 Message scheduling

Type	Frequency
1	Every second
3	The 10th second after the first measurement, then every 10 seconds after that
9-3	Every second
18	Every second
19	Every second
22	The 5th second after the first measurement, then every 10 seconds after that
23	The 4th second after the first measurement, then every 10 seconds after that
24	The 4th second after the first measurement, then every 10 seconds after that
59-sub, 13	The 5th second after the first measurement, then every 10 seconds after that
1004	Every second
1006	Every 10 seconds
1008	Every 10 seconds
1013	Every 300 seconds

APPENDIX

C

Troubleshooting

In this appendix:

- LED conditions
- Receiver issues

LED conditions

An LED that is flashing quickly indicates a condition that may require attention, and an unlit LED indicates that no operation is occurring. The following table describes some LED conditions, possible causes, and how to solve them.

Condition	Possible cause	Solution
The SV Tracking LED is lit solidly and the Logging/memory LED is flashing slowly.	The receiver is in Monitor mode, ready for new firmware to be loaded or new options to be added.	Turn off or turn on the receiver. Load the latest version of the firmware, which you can download from www.trimble.com/support
The SV Tracking LED is flashing rapidly.	The receiver is tracking fewer than four satellites.	Wait until the SV Tracking LED is flashing slowly.
The SV Tracking LED is not flashing	The radio antenna cable and GPS antenna cable are mixed up.	Make sure that the GPS antenna cable (with the yellow over-mould) is connected between the yellow TNC connector marked GPS and the GPS antenna.

Receiver issues

The following table describes some possible receiver issues, possible causes, and how to solve them.

Issue	Possible cause	Solution
The receiver does not turn on.	External power too low.	Check the charge on the external battery, and check the fuse if applicable. Replace the battery if necessary.
	Internal power too low.	Check the charge on the internal batteries and replace if necessary.
		Ensure battery contacts are clean.
	External power not properly connected.	Check that the Lemo connection is seated properly.
		Check for broken or bent pins in the connector.
	Faulty power cable.	Try a different cable.
		Check pinouts with multimeter to ensure internal wiring is intact.
Receiver does not log data.	Insufficient internal memory.	Delete old files using the GPS Configurator or Trimble Survey Controller software, or by holding down the Power button for 30 seconds.
	The receiver is tracking fewer than four satellites.	Wait until the SV Tracking LED is flashing slowly.
The receiver is not responding.	Receiver needs soft reset.	Power down the receiver and power back up.
	Receiver needs full reset.	Hold down ⏻ for 30 seconds.
		If you want to retain data files, remove the CompactFlash card first.
Reference receiver is not broadcasting.	Port settings between reference receiver and radio are incorrect.	Using the Trimble Survey Controller software, connect to the reference radio through the receiver. If no connection is made, connect directly to the radio and change the port settings. Try to connect through the receiver again to ensure that they are communicating.
	Faulty cable between receiver and radio.	Try a different cable.
		Examine the ports for missing pins.
		Use a multimeter to check pinouts.
	No power to radio.	If the radio has its own power supply, check the charge and connections.

Issue	Possible cause	Solution
Roving receiver is not receiving radio.	Reference receiver is not broadcasting.	See above.
	Incorrect over air baud rates between reference and rover.	Connect to the roving receiver's radio and check to ensure it has the same setting as the reference receiver.
	Incorrect port settings between roving external radio and receiver.	If the radio is receiving data (the Logging/memory LED is flashing) and the receiver is not getting radio communications, use Trimble Survey Controller to check that the port settings are correct.
	The cellular modem does not have hardware flow control enabled.	Disable flow control on the modem. Use a special cable. For more information, refer to the document *Using Cellular and CDPD Modems for RTK*, which is available from your Trimble reseller.

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Standard Operating Procedures for Trimble 5700 RTK System June 2009

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Equipment

- Trimble Survey Controller (TSCe).
- Trimble 5700 receiver.
- 5700 receiver antennae.
- Two GPS batteries.
- GPS satellite dome (Zephyr).
- GPS cable: connects dome to GPS port on 5700 receiver.
- Serial cable: connects TSCe to com 1 on 5700 receiver.
- Staff: two meters in height when measured from the bottom tip to the bottom of the GPS dome. Included with the staff is a cradle attachment for the Trimble Survey Controller.

How to perform a GPS Quality Control test

1. Location: the standard QC checkpoint is located at OP-1 between the two bombs. The checkpoint name is OP1-C. Written on one of the bombs is the Easting and Northing coordinates of checkpoint OP1-C.
2. Assemble GPS equipment. Check to make sure the batteries are charged by looking at the battery indicator lights on the 5700 receiver. Also, check the 5700 receiver's satellite and radio indicator lights. Both lights should be blinking at consistent intervals.
3. Trimble Survey Controller procedures when measuring a QC point:

- When in TSCe main menu (Figure 1), select Files> Open Job. Select desired job name (Figure 2). Once loaded the name will be displayed in top left corner, and Survey Controller will return to main menu. Once a job has been selected, it will remain the active job even if the system is powered Do not change the Job unless you are required to.

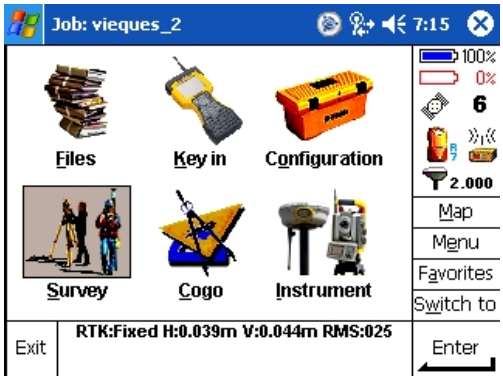


Figure 1.

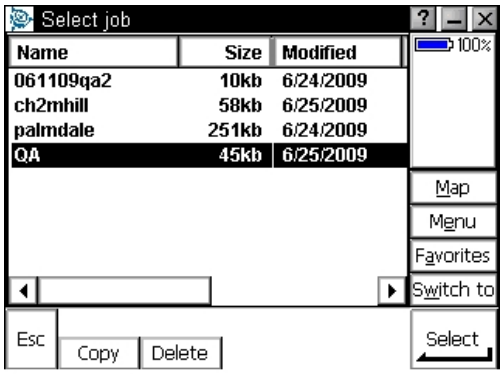


Figure 2.

4. Measuring a Point

- From the main menu select Survey>RTK>Measure Points (Figure 3). A new window will appear prompting for point name and code. Enter the desired point name and accompanying code (Figure 4). The QC point naming convention is the date followed with "gpsqc". The code is the point's location, typically OP1-C.

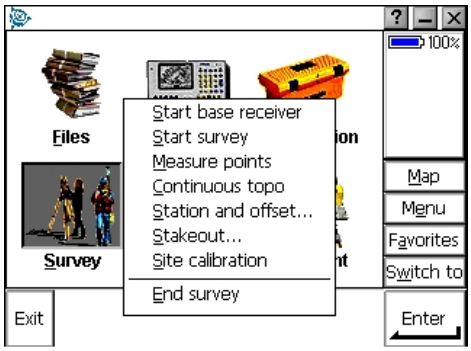


Figure 3.

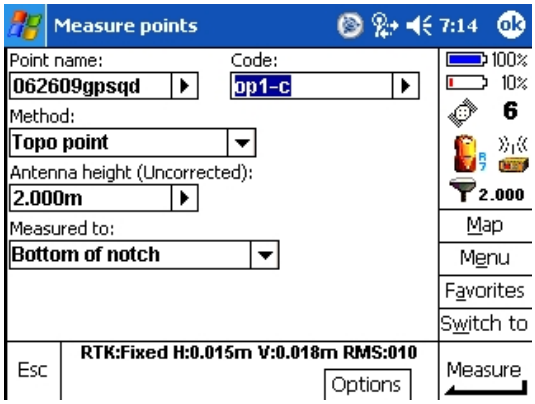


Figure 4.

- Before measuring the point, check to the bottom middle of the screen to make sure there is a "fixed" position (Figure 4). If the RTK is in "float" (Figure 5) or there is a "poor PDOP" message, do not measure the point. More about "float" will be addressed in the troubleshooting section of the SOP.

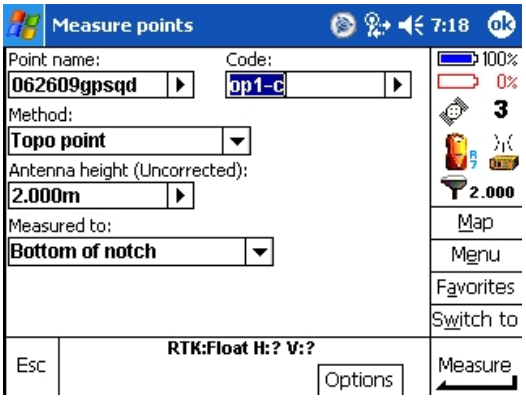


Figure 5.

- There is a small black circle on the concrete labeled “qc point”. Place the staff point inside this circle and use the bubble on the field staff level to center the GPS antennae on the QC checkpoint.
- Once the GPS antennae is positioned and leveled hit the “measure point” button in the bottom right corner of the TSCe screen. A timer will appear and count down, typically between 3-5 seconds, during which the staff must remain leveled and on the point.
  When the countdown is complete, tap the “enter” button in the bottom right corner. A new window will appear, tap the “store” button in the bottom right corner (Figure 6).

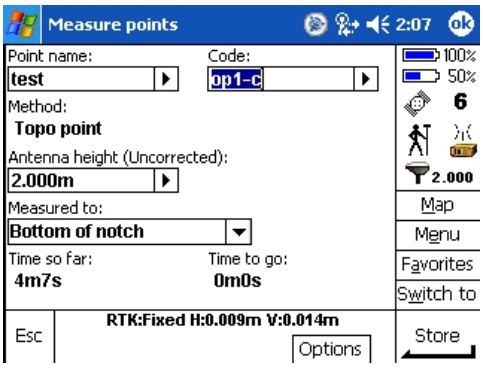


Figure 6.

- To check the coordinates of the QC point, from the main menu tap Files>Review Current Job. Select the point name that matches the QC point name and tap (Figure 7). The data quality objectives for RTK GPS must be within 10cm of the original point location. Compare the original point coordinates to the QC point coordinates. If the QC point’s Easting and Northing is measured to within 10cm of the original then it has passed the QC test and can be used throughout the day. If it fails then measure the point again. If the QC point fails a second QC, test the check the equipment to see if it is functioning properly. Also, check the GPS base station to see if it is setup correctly.

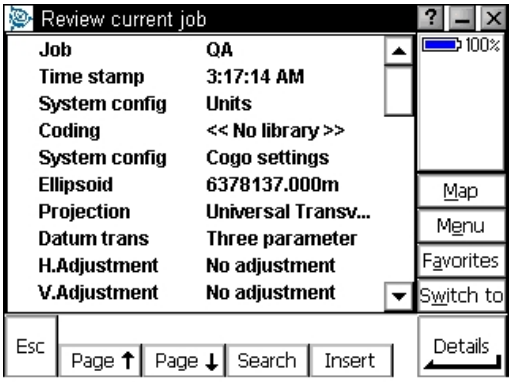


Figure 7.

How to stakeout a GPS point

1. When reacquiring a GPS coordinate use the "stakeout" function on the TSCe to guide you to the point's coordinates. Using the stakeout function is similar to measuring a point but instead of you measuring a new position, the GPS will guide you to a known coordinate
2. In the Main Menu on the TSCe screen select Survey>RTK>Stakeout. See Figure 3.
3. Select a point name from the list of points. If the point name does not appear on the list then it has not been added. Select "add" on the bottom of the screen (Figure 8). Then select "all points". All points stored in the TSCe "linked files" will be added to the point list. Select the point you want to stakeout.

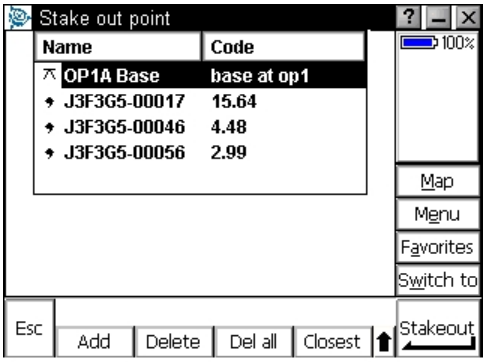


Figure 8.

4. A new window will appear with the direction of the desired point indicated with an arrow. Meters north, south, east, or west (Figure 9) also lists the offset.

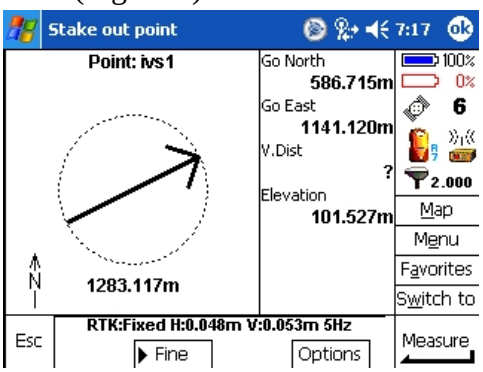


Figure 9.

5. When you are within 1m of the point the directional arrow will change to crosshairs, and the point will be represented by two circles inside of one another (Figure 10).

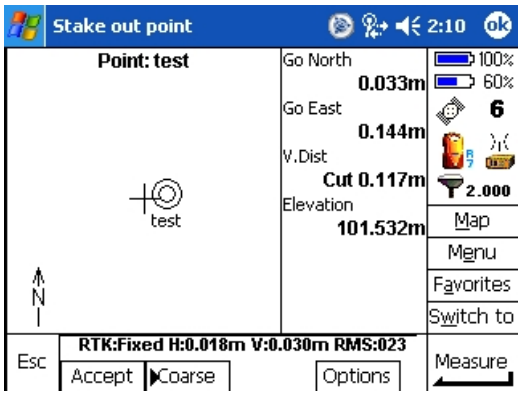


Figure 10.

6. Position the crosshairs inside the inner circle with the staff leveled, and select “measure” in the bottom right corner (Figure 11). The screen will change, prompting the user to enter a new point name and associated code (Figure12). Once completed, tap “measure” and a countdown will begin.

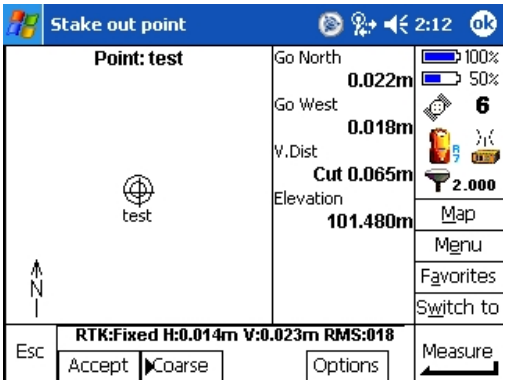


Figure 11.

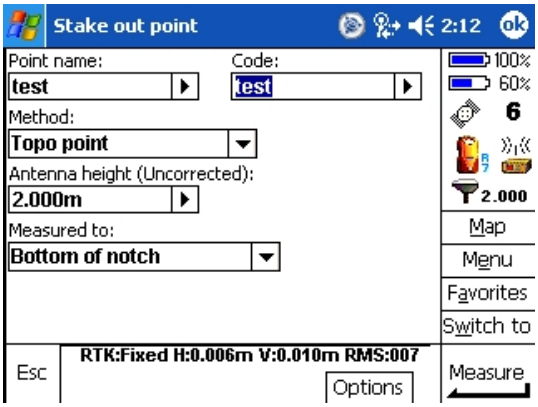


Figure 12.

7. After the countdown, tap “store” (Figure 13).

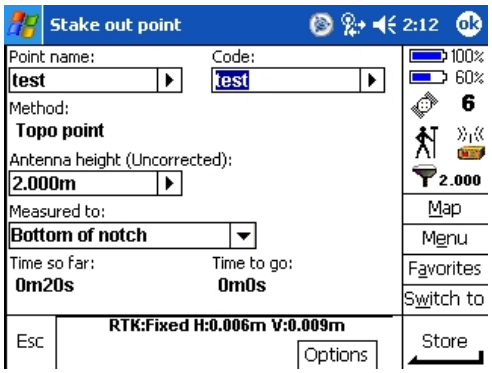


Figure 13.

8. The window will change to indicate the computed offsets of the new stakeout versus the original point (Figure 14).

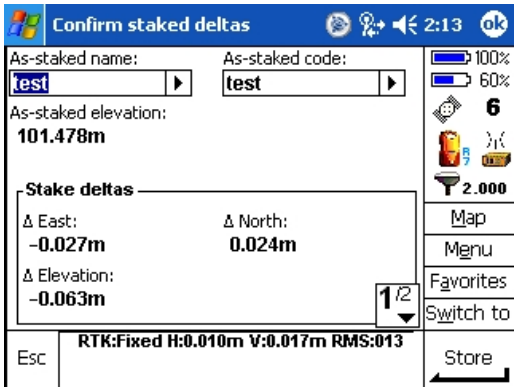


Figure 14.

How to download data

1. From the main menu select Files>Import/Export>Send ASCII Data (Figure 15). In file format, select Comma Delimited (.CSV).
2. Send to “Trimble Data”. Trimble Data is a folder in the TSCe’s file directory.
3. To name is where you enter what the file you are creating is going to be called.
4. The remaining drops down menus have “fields”. The “fields” are columns in the .CSV file format and are similar to columns in an Excel file but unlike Excel files .CSV format does not have headers. Point name is assigned Field 1. Point Code is assigned Field 5. Northing is assigned Field 2. Easting is assigned Field 3. Elevation is assigned Field 4.

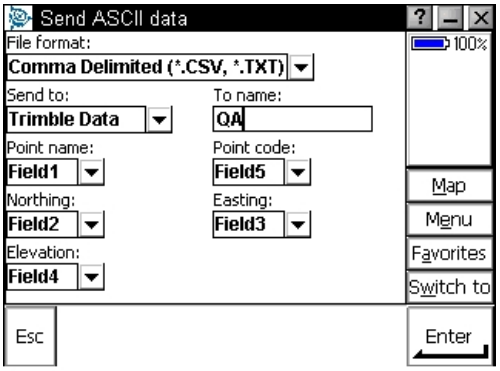


Figure 15.

5. Select enter and the file is created and stored in the “Trimble Data” folder.
6. To transfer the file from the TSCe to a different computer you will need the TSCe, a multi-port connector for TSCe controller, a USB cable. In addition, Microsoft ActiveSync software must be installed on the computer downloading the data otherwise you will not be able to connect the computer with the TSCe (Figure 16).

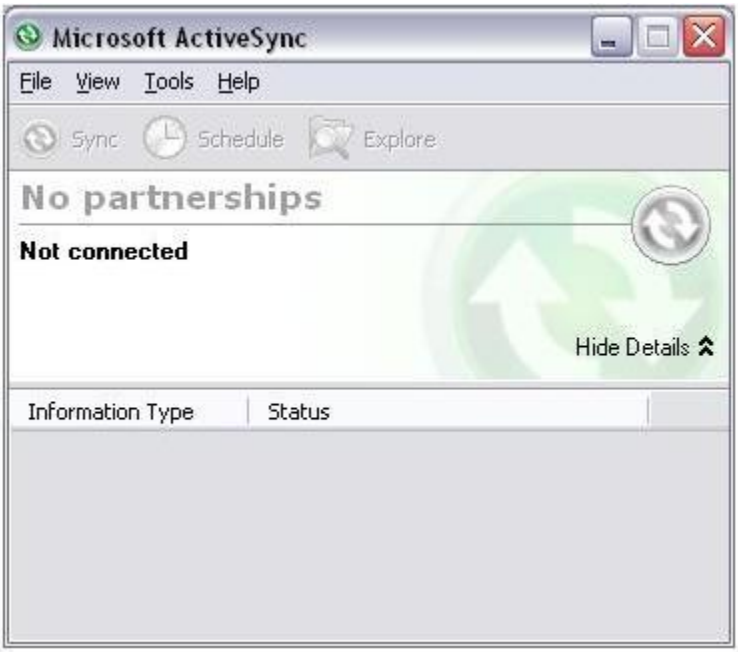


Figure 16.

7. Attach the multi-port connector to the TSCe then connect the TSCe to your computer with the USB cable. When connected with the USB cable Microsoft ActiveSync will start. A window will appear on the TSCe screen asking you to “Connect to desktop?” Select “Yes”. ActiveSync will indicate your computer is connected to a mobile device and prompt you to synchronize the two devices. Do not synchronize your computer with the TSCe. Select “Cancel” and you will be signed on to the TSCe as a “Guest”. This will allow you to transfer files between the two devices but not change or delete files.
8. In the ActiveSync main menu, select “Explore”. Double click on “Disk” folder then double click on the “Trimble Data” folder.
9. Select the file you created and copy it from the TSCe to your computer.

How to uploaded data to the TSCe

1. To upload files to the TSCe you will need the TSCe, a multi-port connector for TSCe controller, a USB cable. In addition, Microsoft ActiveSync software must be installed on the computer downloading the data otherwise you will not be able to connect the computer with the TSCe (Figure 16).
2. Types of files you can upload to the TSCe are .CSV, .SHP, .DBX, etc. The most common file you will need to upload to the TSCe will be .CSV files, which contain point names and coordinates. Comma Delimited files (.CSV) can be created in Excel but the file must be saved as a .CSV to work properly on the TSCe.

3. Attach the multi-port connector to the TSCe then connect the TSCe to your computer with the USB cable. When connected with the USB cable Microsoft ActiveSync will start. A window will appear on the TSCe screen asking you to “Connect to desktop?” Select “Yes”. ActiveSync will indicate your computer is connected to a mobile device and prompt you to synchronize the two devices. Do not synchronize your computer with the TSCe. Select “Cancel” and you will be signed on to the TSCe as a “Guest”. This will allow you to transfer files between the two devices but not change or delete files.
4. In the ActiveSync main menu, select “Explore”. Double click on “Disk” folder then double click on the “Trimble Data” folder.
5. Select the file you created and copy it from your computer to the TSCe “Trimble Data” folder.
6. Disconnect the TSCe from your computer.
7. On the TSCe main menu, select “Files” then “Properties of current job”. See Figure 17.

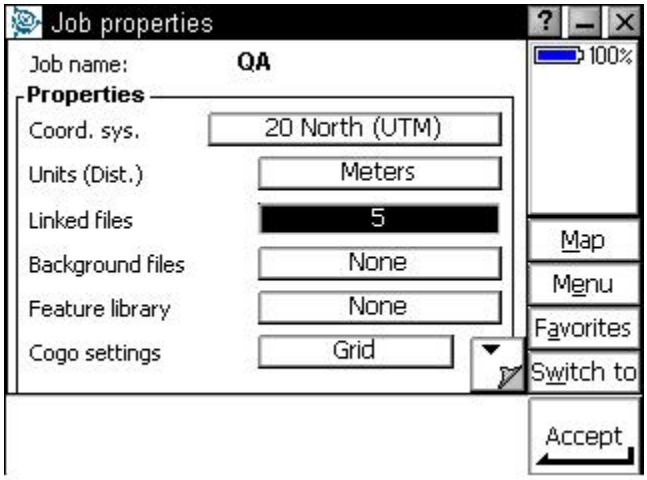


Figure 17.

8. You will need to link the file to the TSCe’s current job. Select “Linked files” then select the file you want to link (Figure 18). When a file is linked to a job, it will have a check mark beside the file name. Multiple files can be link to a TSCe job. Linked files cannot be overwritten when linked to a job. If you are trying to export a file with the same name as a linked file, you will get a “file error” and the file will not be exported.

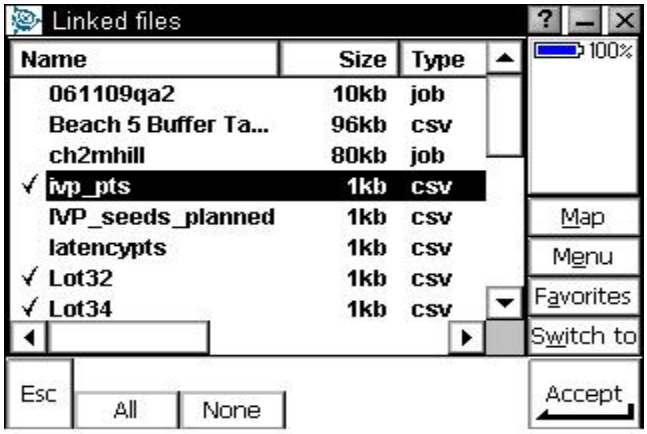


Figure 18.

Trouble shooting common GPS problems

1. *Loss of radio link:* when the GPS receiver is not receiving radio corrections from the GPS base station you will not be able to measure points or stakeout points accurately. The radio indicator light on the 5700 receiver will stop blinking and/or will be blinking at inconsistent intervals. Loss of radio can be caused by being too far away from the base station radio or by not having "line of sight" to the base station radio. Radio transmission can be interrupted when the signal is blocked by a being behind a mountain or when trying to use the GPS receiver when up against a steep bank or cliff.
2. *Lack of satellites:* For RTK quality, GPS the satellite icon must be receiving a minimum of five satellites. The number of satellites appears on the right side of TSCe main menu. A lack of enough satellites will cause the GPS receiver to "float". The "float" indicator is at the bottom of the TSCe screen when measuring or staking out a point. A lack of satellites can be caused by have the satellite signal blocked by objects such as overhanging tree branches or by not having enough satellites overhead. When the system begins to "float" make sure there is nothing blocking the GPS dome. If the system is not being blocked by physical objects then check the satellite indicator and wait until there are more satellites. Usually, additional satellites will appear within 15 minutes as the satellites orbit the planet.
3. *Battery power:* Battery strength for the 5700 receiver is indicated on the TSCe by the battery icon and displays remaining strength as a percentage. Battery power can also be checked on the front of the 5700 receiver with two lights labeled "A" and "B". A yellow light indicates a battery in reserve. The green light indicates the current power source. Before a battery drains, the green light will blink rapidly with an audible warning from the TSCe controller. The reserve battery will then change to green, and become the primary power source.

USER GUIDE

GeoExplorer® 2008 series

Trimble

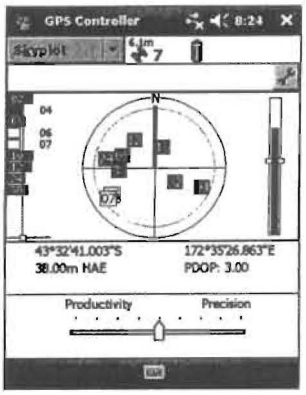
Starting the GPS field software

Do one of the following:

- From the *Today* screen, tap the *GPS* softkey in the menu bar.
- Tap / *Programs* and then select the GPS field software, for example *GPS Controller*.

When you first open any Trimble GPS field software, the Skyplot section is displayed.

Viewing available GPS satellites



Use the graphical Skyplot section or the Satellite Info section in the Trimble GPS field software to view detailed GPS information, and to adjust the quality and yield of the GPS positions you are receiving.

***Note** – To receive signals from GPS satellites, the handheld must have a clear view of the sky. GPS positions may not always be available, particularly in or near buildings, in vehicles, or under tree canopy.*

Resetting the GPS receiver

Trimble GPS field applications all have options to reset the receiver to:

- delete the almanac
- delete information stored on the last known position
- restart the receiver
- reset the GPS receiver to factory default settings

Ensuring the accuracy of your GPS data

GeoExplorer 2008 series handhelds are high performance GPS receivers that calculate very accurate GPS positions.

To correct errors in the collected data and to further improve the accuracy of the GPS positions, use differential GPS. Differential GPS (DGPS) requires one or more additional receivers, called ***base stations*** or reference stations, which are located at known points. Data collected at the base stations is used to determine GPS measurement errors and compute corrections to these errors. These corrections are then applied to data collected in the field either in real time or during postprocessing. For more information, see Differential GPS explained, page 73.

The three different models in the GeoExplorer 2008 series offer three levels of DGPS accuracy:

- The GeoXM handheld provides reliable accuracy to within 1 to 3 meters with real-time or postprocessed differential correction.
- The GeoXT handheld uses EVEREST multipath rejection technology to provide submeter accuracy with real-time or postprocessed differential correction.
- The GeoXH handheld uses EVEREST multipath rejection technology as well as H-Star technology to provide subfoot (30 cm) accuracy using the internal antenna, and 10 cm to 30 cm accuracy using the optional Zephyr antenna, with real-time or postprocessed differential correction.

***Note** – To achieve subfoot accuracy with a GeoXH handheld, data must be collected using Trimble field software (TerraSync software, the GPScorrect extension for ESRI ArcPad software, or a custom application developed using the GPS Pathfinder Tools Software Development Kit).*

For more information, refer to the datasheet for your model of handheld.

Where the DGPS infrastructure does not meet subfoot accuracy requirements (for example, the base station provides L1 corrections only, or is at a distance greater than recommended), the GeoXH handheld typically achieves submeter accuracy.

The list below identifies the most important settings and techniques that you can use in the field to improve the accuracy of your data:

***Note** – This list assumes that you are using Trimble GPS field software, and lists items in order of most important to less important.*

1. If you are using TerraSync software to collect data, use accuracy-based logging. For more information, see page 67.
2. Use real-time differential corrections. If you are using a GeoXH handheld and have access to dual-frequency corrections from a VRS network, use the corrections from the VRS network. For more information, see page 68.
3. Configure the GPS settings for the receiver to increase the precision of your data, and to minimize the effect of atmospheric interference and poor satellite geometry. For more information, see page 70.
4. Connect to an external antenna, if you have one. For more information, see page 71.
5. If you are using a GeoXT handheld, configure the data collection software to log carrier data. If you are using a GeoXH handheld, the data collection software logs H-Star data, by default. For more information, see page 72.
6. Plan GPS data collection around the times of the day when satellite geometry is best. For more information, see page 73.

Geophysical Investigations with The Geonics EM61-MK2 and EM61

Operational Procedures And Quality Control Recommendations

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Geophysical Investigations with the Geonics EM61-MK2 and EM61
Operational Procedures and Quality Control Manual

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Chapter 1 Introduction

This document is intended to provide an example of quality control procedures for the use of the Geonics EM61-MK2 and EM61 instruments. This guide is not intended to be, or to be used as, an industry standard for use of the Geonics series of electromagnetic (EM) instruments. The primary goal of this manual is to introduce procedures for surveying that will maximize data quality and promote documentation of data collection and processing procedures used by consultants. Geonics Limited would like to acknowledge for their considerable input into this document, Naeva Geophysics Inc., Geosoft Inc. and the U.S. Army Engineering and Support Center. Additional input has been provided by Peeter Pehme and Dr. John Greenhouse of Hyd-Eng Geophysics (Dillon Consulting) who, as always, were willing to offer their time and considerable experiences.

1.1 Primary Purpose of Manual

The primary purpose of this manual is to address quality control procedures to be used in data acquisition, navigation, data processing and transfer, and quality control of products delivered to the end user (client) of geophysical investigations (primarily with the EM61-MK2). Consideration of these procedures will also assist the client in quality assurance evaluations of consultant performance.

1.2 Origin of Document

This manual draws on existing engineering and operational manuals. References are made to these documents for obtaining detailed information on specific topics.

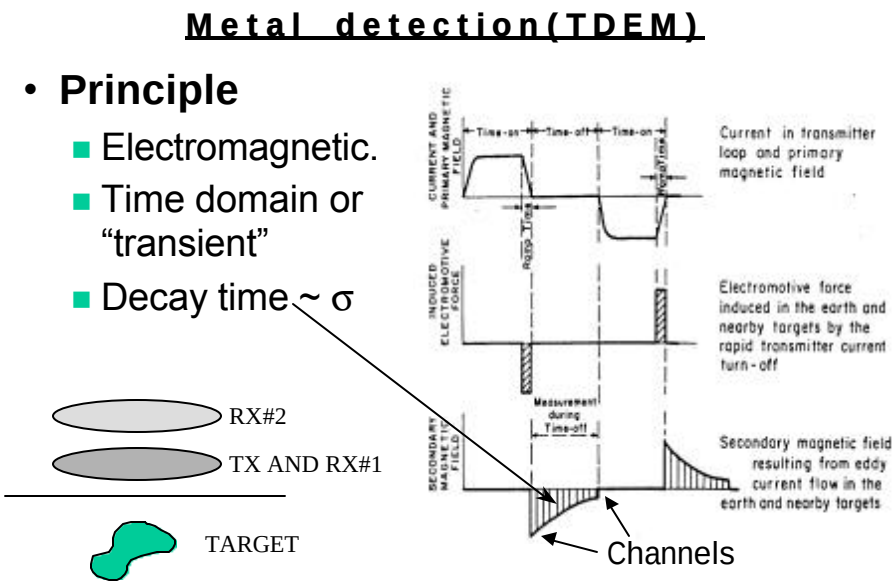


Figure 2.1 Time Domain Theory

The EM61-MK2 is a time domain metal detector manufactured by Geonics Limited of Mississauga, Ontario. The Geonics systems transmit a time varying electromagnetic pulse in the subsurface. The instrument is used for the detection of ferrous and non-ferrous metallic objects primarily in the environmental/engineering and unexploded ordnance (UXO) applications.

The EM61-MK2 consists of a coincident transmitter (Tx) and receiver (Rx) coil and a second receiver coil located 30 centimetres above the Tx/Rx coil. The Tx coil is energized by a pulse of current and the Rx coils measure the response decay at fixed moments in time.

The EM61-MK2 can provide output from four time gates geometrically spaced in time after the termination of the transmitter pulse. This feature allows discrimination between different types of targets based on the time-decay rate of the response. This discrimination technique works well for simple shaped targets with all three dimensions (x, y and z) being approximately equal,

it has also shown to be useful, however, at some military test ranges. For additional description of the EM61-MK2 please refer to Geonics Limited Technical Note TN-33[1].

Chapter 3 Planning

The following list for planning geophysical surveys is limited to a brief description of major elements for brevity. These elements are standard for planning any geophysical investigation and have been referred to in various documents. Many of these elements are considered to be standard by the Environmental and Engineering Geophysical Society (EEGS).

3.1 Research Site History.

a. Review all previous investigation reports. The previous usage of the site and the likely composition and depth of targets should be defined in this stage of planning.

b. If possible, conduct interviews with personnel formerly assigned at site. One goal of the interviews may be to obtain local information and anecdotes on the suspected target areas.

3.2 Research Site Geology.

a. Review surficial geology: Obtain geologic maps and literature for the site.

b. Review bedrock geology: Use sources above to obtain information.

3.3 Preparation of Geophysical Investigation Plan.

a. Determine survey type: Random, Fixed Pattern Transects, or Detailed. Survey type is dependent on the objectives of the investigation, whether the goal is to conduct Geophysical Sampling, Geophysical Mapping, or a more detailed Geophysical Investigation.

[1] Technical Note TN-33, Miro Bosnar, Geonics Limited, March 2001.

b. Determine geophysical methods and procedures proposed for the investigation: Methods and procedures are determined by consideration of all factors described above, as well as type and expected depth of targets. Topography, vegetation, and the presence of cultural features must also be considered in the selection of instruments.

c. Determine required data density, based on type of investigation: Size and depth of expected targets, and method used for detection will dictate minimum requirements for line and station spacing.

d. Define method of navigation, means of location and mapping: Describe procedures and equipment to be used in data collection to ensure accurate location of data points. Means of location and mapping points, whether by GPS, ultrasonic or through conventional surveying of grid corners should be defined.

e. List survey equipment and services: Prepare list of items needed to perform survey, and services required. List should include sources of supplies and rental sources of equipment that may provide backup instruments in the event of instrument malfunction.

f. Describe Data Storage, Transfer and Archiving.

g. Describe Quality Control procedures to be performed: steps to ensure proper instrument function, accurate mapping and location of anomalies, and repeatability.

h. Describe Procedures for Reacquisition: methods of reacquisition of anomalies.

i. Define Work Schedule, project completion, schedule of deliverables to client.

3.4 Site Visit.

A site visit is sometimes necessary (usually recommended) prior to designing the survey to identify the various physical characteristics of a site and the potential problems that may limit the success of a geophysical investigation. A successful site visit gathers local information that may be crucial to the planning and implementation of a geophysical investigation. The factors below must be evaluated during the site visit:

a. Topography; density, type and distribution of vegetation. Notation must be made of areas of potential interference.

b. Evaluate road access to survey areas; condition of roads and trails. Determine whether 2 wheel drive, 4 wheel drive, or All Terrain Vehicles are necessary for access. Map useful trails or roads that are not on available maps. Look for locked gates or other barriers that may hinder access.

c. Visit local landowners (if necessary) to discuss right of entry through private lands.

Chapter 4 Amplitude Response and Depth of Detection

4.1 Introduction.

Test measurements have been made at numerous sites on inert ordnance items at various depths and orientations. It has been shown that the approximately dipolar amplitude response of small target items is inversely proportional to the distance of separation between the sensor and the anomaly source. Theory as well as testing has also revealed that vertical items generally have a greater EM amplitude response than horizontal items. Figure 4.1 depicts a number of EM61 amplitude response measurements over horizontal ordnance items and calibration spheres at various depths.

a. The instrument noise level for a well maintained and calibrated EM61-MK2 is about 1 to 1.5 mV (for the EM61 or channel #3 of the EM61-MK2). Therefore, the depth at which each ordnance type response reaches this noise level is the ultimate detection depth for that object (ideal conditions, no other noise). At various locations across a remediation site, the local terrain noise will reduce the actual detection depths. This value may be estimated by superimposing a noise threshold model over Figure 4.1. It is inappropriate to speak of a 'typical detection depth' for a particular instrument without considering terrain noise.

   The standard EM61-MK2 cannot detect single objects at depths much greater than 3-4 meters. For objects greater than 3 meters, the high power and/or larger transmitter loops are generally recommended.

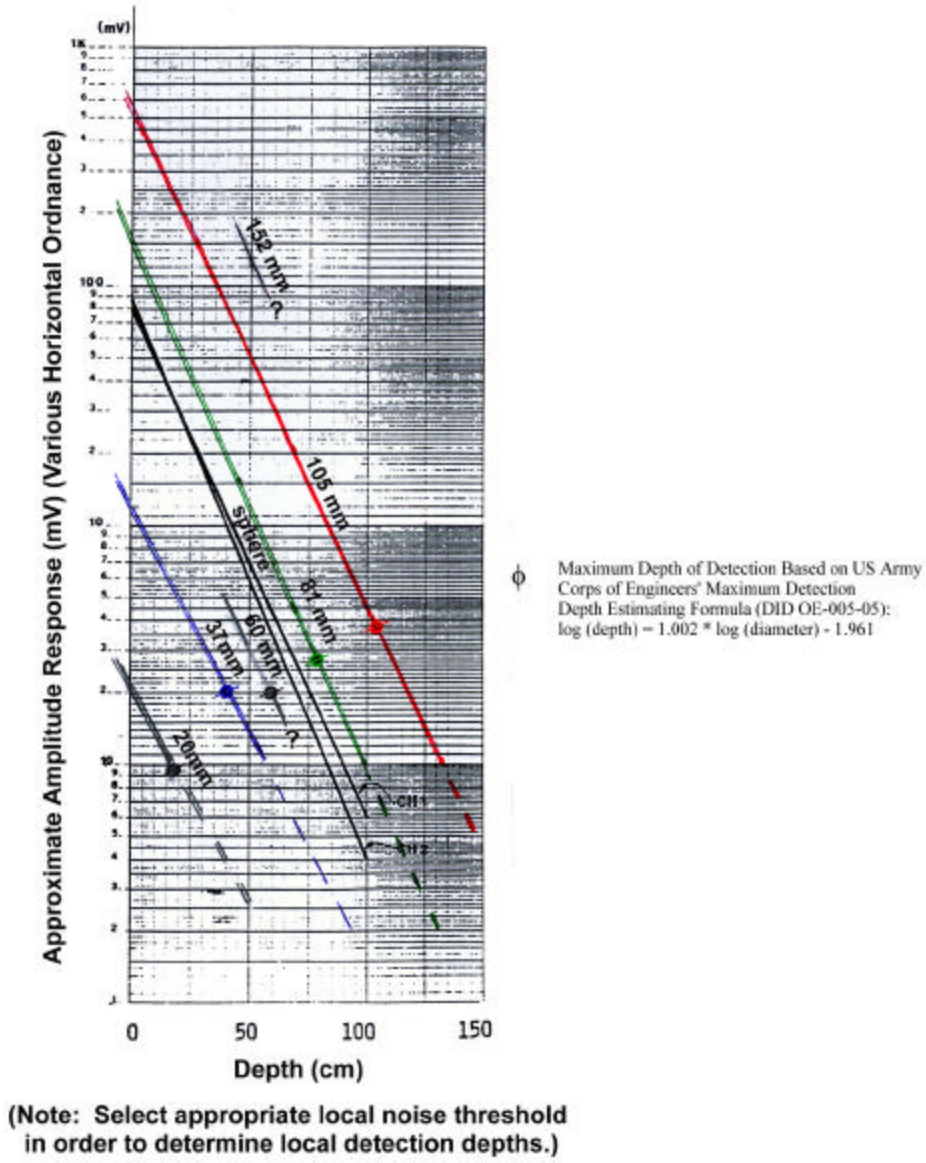


Figure 4.1 Detection Depths

b. The Ordnance Detection and Discrimination Study (ODDS) conducted by Parsons Engineering Science for the Corps of Engineers at the former Fort Ord in California, in July 2000, generated excellent examples of static test data using vertical gradient magnetometer and EM (time domain and frequency domain). Figures 4.2 and 4.3 were compiled using ODDS data, illustrating their findings on maximum depths of detection for 187 different ordnance items, ranging in size from a 14.5 mm trainer M181 projectile, to a 155 mm projectile. It is important to note that all of these measurements were

recorded using a special non-metallic platform, raised above the ground surface; they are essentially free-air measurements, with no terrain noise. The following comments can be made:

(1) Maximum depth tested for each item was the calculated maximum depth of penetration for soils at Fort Ord. For the EM61, best and worst orientations were generally with the long axis of the item vertical, and horizontal, respectively.

(2) Readings as low as 1.49 mV were recorded as detectable for the EM61, and 1.31 mV for the EM61-HH. While these numbers may be useful in calculating detection depths in an ideal environment, in a real survey noise levels from a variety of sources will probably necessitate a higher threshold. Additionally, the better signal to noise ratio and earlier time gates of the EM61-MK2 will improve the detection level of both smaller and deeper targets.

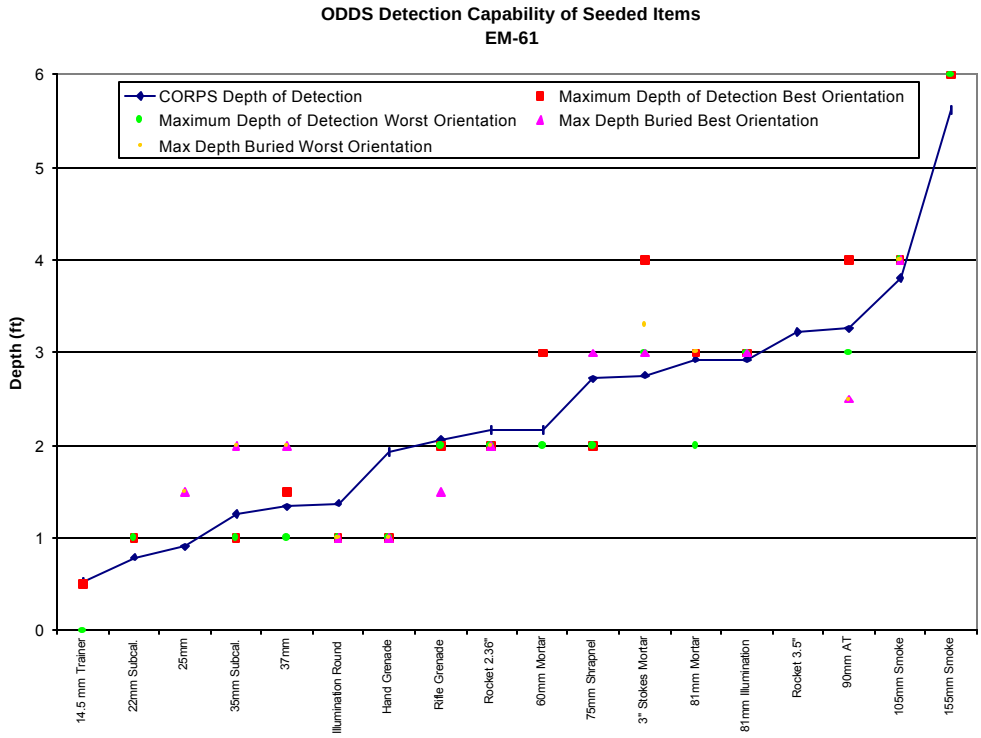


Figure 4.2 Fort Ord Detection Depths –EM61

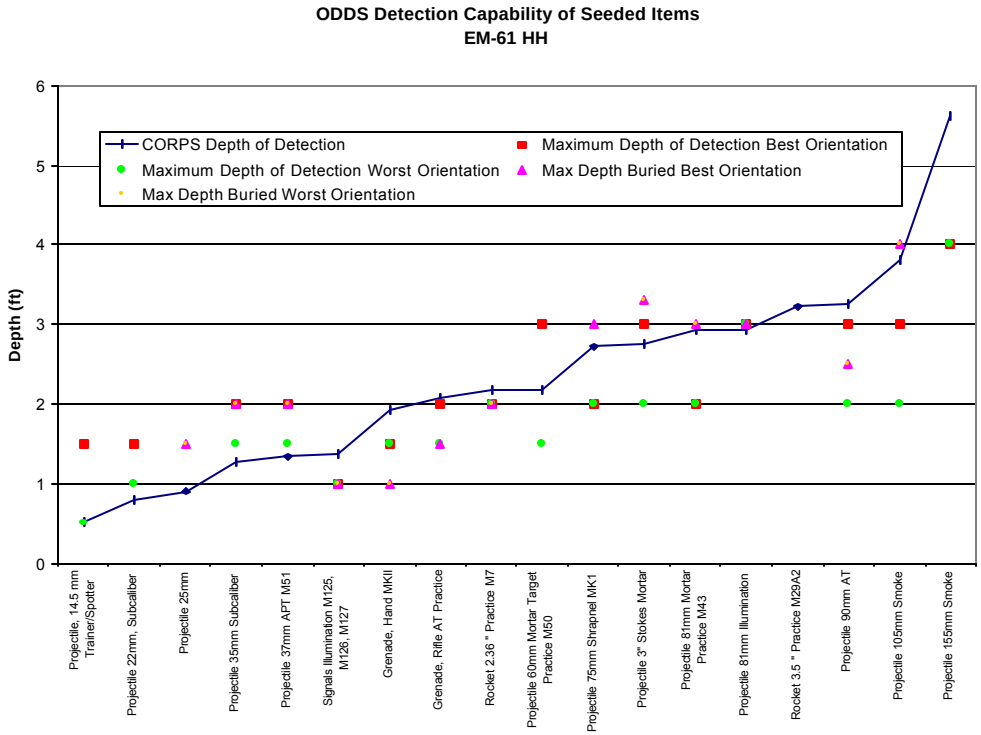


Figure 4.3 Fort Ord Detection Depths – EM61-HH

4.2 Geophysical Noise

a. The responses of targets may be detected only if they are greater than the background noise level. Geophysical noise (not sensor sensitivity) is therefore the limiting factor in determining thresholds and detection depths. The noise encountered in geophysical surveys is generally of four types:

- Instrument Noise
- Ambient (Disturbance Field) Noise
- Motional or Dynamic Noise (mechanical vibration, etc.)
- Terrain Noise (site-specific, repeatable response of rocks, soils, and metal clutter)

b. Instrument noise is internal and intrinsic to the instrument. It is generally, by design, of much lower amplitude than other sources of background noise.

c. Ambient noise is induced in the sensors by outside fields in its vicinity. It can be caused by nearby utilities, motors, radios, generators, radar, and other electrical or electromagnetic devices. GPS electronics and radios are common sources of ambient noise. An extreme example of this type of noise is illustrated in Figure 4.4 displaying EM61 data collected in the close vicinity of ***high tension*** power lines.

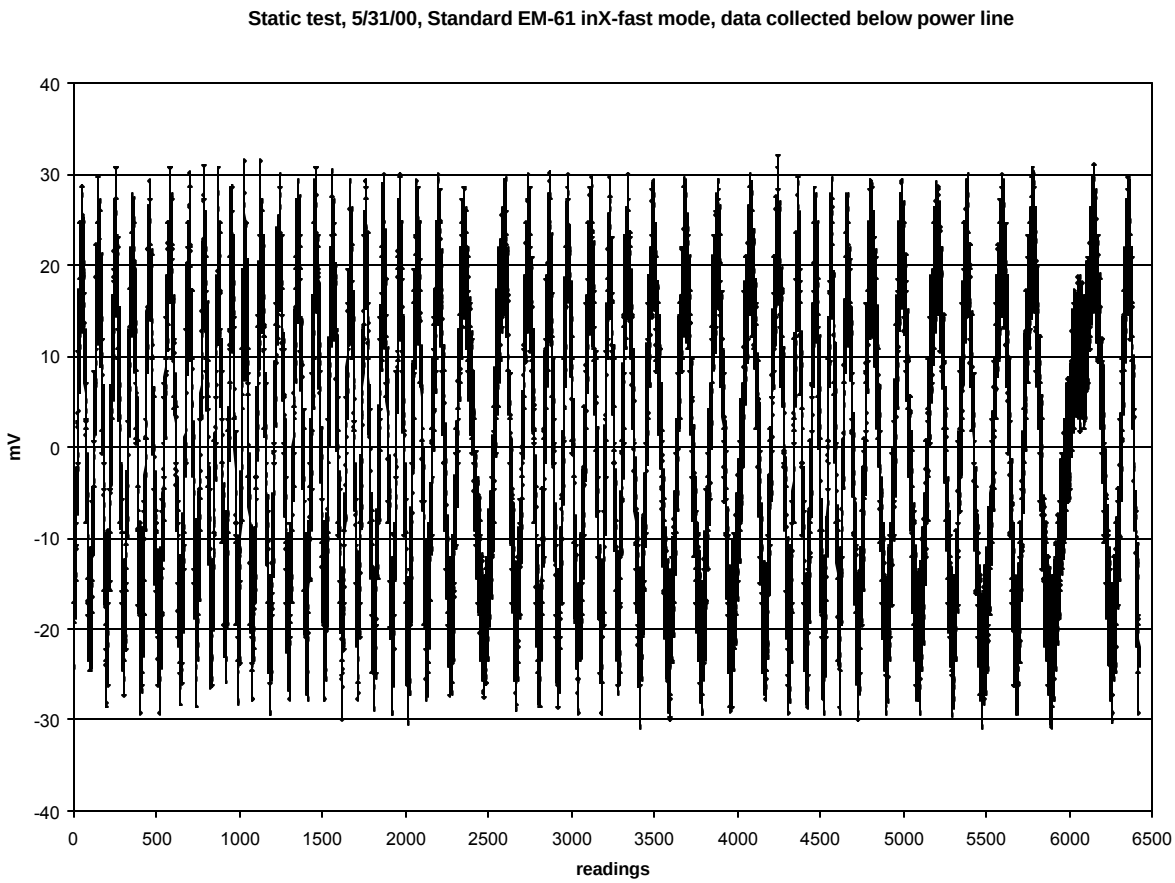


Figure 4.4 EM Noise

d. Motional noise is caused by mechanical vibration of the instrument and metal on the operator or instrument (wheels, etc.). It can occur anytime the instrument is moving. Varying the EM61-MK2's coil(s) orientation while surveying may generate a high frequency (depending on rate of change) sinusoidal response which can make interpretation of smaller targets difficult. This "noise" likely results from varying the

instruments sensors in a manner that the coupling with the earth's magnetic field is changed.

e. Terrain noise is cause by real and repeatable instrument response to highly magnetic rocks and soils, and metal clutter. The term terrain refers to the sources of response that are actually present in or on the ground. It is usually the largest noise component and often the limiting factor in geophysical detection and interpretation.

4.3 Filtering Noise.

a. One frequently hears references to 'filtering the noise'. Short wavelength and long wavelength noise can be suppressed by filtering. Unfortunately, terrain noise is non-random (repeatable) and often contains the similar wavelengths as target responses. It cannot be removed by spatial filtering.

b. Static (bench) tests measure the sum of instrument and ambient noise (and also instrument drift). Dynamic tests along an actual survey line are necessary in order to measure motional and terrain noise. Emplacement of one or more calibration objects permits evaluation of amplitude response. A repeated dynamic test survey line also measures positional variation.

Chapter 5 Equipment Functionality and QC Tests

The required equipment tests and frequency of testing is summarized in Table 5.1. Pass / Fail criteria are listed in the Instrument Test Checklists included at the end of this chapter.

5.1 Out of Box Equipment Tests

Non-functioning equipment arriving at the site will cause delays in surveying. Worse yet, improperly functioning equipment may result in unreliable data, increasing false alarms or missing targets. For these reasons out of box equipment tests are recommended to ensure instruments are operating correctly:

a. Inventory and inspect all components. Equipment manufacturers and most geophysical rental companies provide a packing list showing all included components. Check that each item is present, and inspect cables, connectors, harnesses, etc. for signs of wear or damage. Spare cables are essential as the cables are often the most vulnerable part of a system.

b. Assemble the instrument and power up.

c. With the instrument held in a static position, and collecting data, move cables to test for shorts and broken wires or pins. Shake cable starting on one end and proceeding to the other. An assistant is helpful to observe any changes in instrument response. If shorts are found, mark cable, set aside and replace.

d. Conduct Static Test, and Instrument Response Test:

   (1) Establish an area for these tests that offers convenient access, is free of metal (surface and sub-surface), and is sufficiently far from roads and power lines, transmitters, etc. to avoid these sources of noise. This same point should be used throughout the duration of the project for the daily static and response tests and for instrument nulling.

   (2) Static Test: The purpose of performing a static test is to determine whether a particular geophysical instrument is collecting stable readings. Improper instrument

function, the presence of local sources of ambient noise (such as EM transmissions from high-voltage electric lines), and instability in the earth's magnetic field (as during a magnetic storm) are all potential causes of inconsistent, non-repeatable readings. The operator must review the readings to confirm their stability prior to continuing with the geophysical survey.

(a) When the instrument has been powered up sufficiently long to warm the electronics (2 to 5 minutes), place the instrument at its normal operating height and orientation so that it will remain stationary and begin data collection. (An alternative to waiting for the instrument to warm up is to begin data collection when the instrument is turned on, thus documenting the time required for readings to stabilize.) Collect readings for a minimum of three minutes after instrument warm-up. Data collected during static tests should be retained for documentation purposes. This site should also be used to "NULL" the EM61-MK2; refer to the operating manual for a detailed explanation of this procedure.

(b) The effects of ambient noise may vary across a project site. Therefore, it may be necessary to perform several static tests across the survey area.

(3) The Instrument Response Test quantifies the response of the instrument to a standard test item. A steel trailer ball is a preferred test item that is easily acquired and transported. A standard 2" diameter trailer ball with integrated shaft could be used as the test item. Leaving the instrument in the same position as used in the Static Test, place the test item below the sensor, and then collect data for a minimum three minute period. The test will document the amplitude of response to the test item and instrument drift.

e. Equipment not functioning properly should be replaced or repaired as quickly as possible.

5.2 Initial Geophysical Instrument Checks

These tests are performed the first day of a geophysical investigation.

a. Six-Line Test: This test can be used for all geophysical instruments, and is illustrated in Figure 5.1.

(1) Use an area that has little background noise and no sources of anomalous responses.

(2) The test lines should be well marked to facilitate data collection over the exact same lines each time the test is performed. Background response over the test area is established in Lines 1 and 2.

(3) A standard test item, such as a steel trailer hitch ball (or any metallic object) will be used for Lines 3 through 6. Heading effects, repeatability of response amplitude, positional accuracy, and latency are evaluated in Lines 3-6.

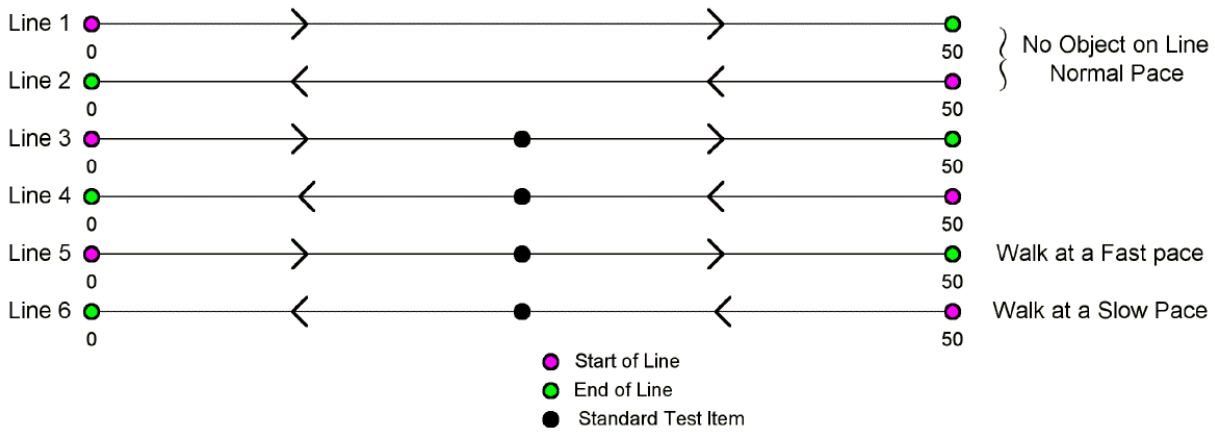


Figure 5.1 Example Test Site

b. Pull-Away Test: This test demonstrates the effects of navigational equipment and/or vehicles used to tow sensors or arrays. With the instrument collecting data in a static (background) test, navigational equipment and/or vehicles, positioned as they would be in the field survey, are pulled slowly away from the sensor to gauge any differences in response. This must be performed twice; once with the navigational equipment (and/or vehicle) power off, the second with the equipment powered up. A simple DC shift may

be observed when the equipment is in normal operating position, compared to values when it is distant, however this is easily removed from the data. If excessive noise is noted, however, steps should be taken to identify the source and correct the problem.

5.3 Suggested Daily Instrument Checks.

a. Cable Shake Test: Prior to collecting data each day, the instrument cables and connectors should be tested for shorts as described in the out of box equipment tests. Faulty cables or connectors will be replaced prior to data collection.

b. Static Test (Background): This test should be performed twice daily in the same location, prior to data collection, and at the end of the day. Data should be recorded during a minimum 3-minute duration static test to demonstrate stability of readings over both the short and long term.

c. Static Test (Response): Following the static background test, a standard test item should be placed below the sensor, and readings recorded for at least 3 minutes. Instrument response of equal amplitude from test to test demonstrates that the calibration of the instrument has not changed. (This test should be repeated when changing batteries.)

d. Personnel Test: The instrument operator moves around the stationary, operating instrument to scan for any effects from remaining metal on the operator.

5.4 Examination of Repeat Data.

A minimum of 5% repeat data is recommended for grid sampling. Repeat lines will be adjacent to one another. A site with a low density of anomalous responses would benefit from a higher percentage of repeat data. When viewed in profile and compared to original data, repeat data provides a means of evaluating the ability of the instrument to respond consistently, and evaluates the positional accuracy of the data. Errors in positional repeatability indicate a problem in the method of navigation.

Test	Frequency of Testing		
	Beginning of Day	Beginning and End of Day	First Day of Project Only
Personnel Test	X		
Cable Shake	X		
Static (Background)		X	
Static (Response)		X	
6 Line Test			X

Table 5.1 Instrument Test Table

5.5 Checklist for Out of Box Equipment Tests

Project Name: _____

Project Location: _____

Design Center POC: _____

Reviewer's Name and Title: _____

Date of Review: _____

	Y	N	N/A
a. Has the equipment been inventoried and inspected for damage or wear?			
b. Has the cable shake test been performed? (Replace any faulty components if necessary)	____	____	____
c. Has a nearby, noise-free site been selected for static background and static response tests?	____	____	____
d. Have the following instrument function tests been successfully performed:	____	____	____
• Static background test demonstrating <20 mV deviation in response for at least 3 minutes?	____	____	____
• Static response test demonstrating <5% deviation in response from test to test?	____	____	____

5.6 Checklist for Initial Instrument Tests

Project Name: _____

Project Location: _____

Design Center POC: _____

Reviewer's Name and Title: _____

Date of Review: _____

	Y	N	N/A
a. Has the six-line test been utilized to evaluate the following factors:			
• Heading effects?	____	____	____
• Repeatability of the response amplitude?	____	____	____
• Positional accuracy?	____	____	____
• Latency?	____	____	____
b. Has the pull-away test been performed and successfully demonstrated no influence from navigational or towing equipment?	____	____	____

5.7 Checklist for Daily Instrument Checks

Project Name: _____

Project Location: _____

Design Center POC: _____

Reviewer's Name and Title: _____

Date of Review: _____

	Y	N	N/A
a. Has the cable shake test been performed? (Replace faulty components if necessary)	____	____	____
b. Has a static background test been performed and demonstrated <20 mV deviation in response over at least 3 minutes:			
• Start of day?	____	____	____
• End of day?	____	____	____
c. Has a static response test been performed and demonstrated <5% deviation in response from test to test:			
• Start of day?	____	____	____
• End of day?	____	____	____
d. Has the operator been thoroughly examined with the geophysical instrument for any sources of response that may not be readily apparent?	____	____	____
e. Has the repeat data been utilized to evaluate the following factors:			
• Repeatability of response amplitude?	____	____	____
• Positional accuracy?	____	____	____

Chapter 6 Data Acquisition

6.1 Survey Design Elements.

a. Line spacing requirements for grid sampling are dependent on the specific geophysical instrument being used and the types of buried targets expected. Geophysical investigations for the more common munitions types (mortars, grenades, projectiles, etc.) that are buried randomly require standardized intervals between lines. The following line spacing has been mandated by some United States military organizations and is recommended for munition site surveys.

	Line Spacing	
Instrument	*English*	*Metric*
EM61 (meter wide footprint)	2.5 ft	0.75 m
EM61/ EM61-MK2 (half meter wide footprint)	1.5 ft	0.5 m
EM61-HH	1 ft	0.3 m

Table 6.1 Line Spacing Recommendations

For other instruments, alternate line separations may be necessary.

In cases where munitions with extremely low amplitude responses are being investigated, it may be necessary to reduce line spacing to one-half the diameter of the receiving coil in the case of EM. Such reductions in line separations will have an adverse affect on production rates. When the objective is to find large, deeply penetrating items or burials (caches, pits, and trenches) line spacing can be increased to suit the situation.

Adequate data density is determined by the same factors as adequate line spacing. However, increasing data density along survey lines usually does not significantly increase survey time or cost. Increased data density improves the likelihood of a reading being taken directly over the peak of an anomaly. The following are minimum data densities for the EM61, EM61-MK2 and the EM61-HH. When operating in automatic sampling mode, the consultant must determine the appropriate sampling rate and operator speed in order to achieve these intervals. As with line spacing, if the objective is to find large, deeply penetrating buried munitions items or burial features, data density may be decreased to suit the situation.

	Data Density	
Instrument	*English*	*Metric*
EM61 (meter wide footprint)	0.66 ft	0.20 m
EM61/EM61-MK2 (half meter wide footprint)	0.66 ft	0.20 m
EM61-HH	0.33 ft	0.10 m

Table 6.2 Station Spacing Recommendations

b. Meandering Path and Transects: These types of surveys are alternatives to grid sampling that may offer advantages in some investigations. Line spacing for a Meandering Path survey is influenced by vegetation density, as denser areas are avoided. Adequate coverage is achieved when the team acquires the same linear footage as would have been covered with grids. Transects use the same criteria to determine adequate coverage, but may use a fixed spacing between lines. When used in this manner transects may be considered as very narrow grids. Data density in both types should meet the requirements listed above. Unlike standard grid sampling, all of the data in Meandering Path and Transect surveys is subject to edge effects. Passing close to or over the edge of an ordnance item reduces the amplitude of the response compared with traveling directly over it. As a result, different thresholds must be considered for selection of anomalies in these types of surveys. Another important difference versus grid sampling is that the collection of repeat data may not be possible.

c. File Naming Conventions: A standardized format for file names will be used throughout the duration of a project, and will be documented. A logical format, incorporating information such as Date, Area, Sector, and Grid # is suggested. For standardized tests that will be repeated twice daily, such as Static Background, the file name should include the date, the type of test, and an indication of whether it is AM or PM. An example for this test is 1210SBAM, for a Static Background test collected the morning of December 10. Unfortunately, the Polycorder provided with the standard EM61 limits the number of

characters for a file name to 7, so one could drop the last letter: 1210SBA. The field PC provided with the EM61-MK2 defaults to a date: time file name (similar to the Trimble standard) that can be edited to include the suggested parameters.

6.2 Operating Procedures for EM61 and EM61-MK2

a. All EM61s have been designed to keep the operator far enough away from the coils so that small amounts of personal metal will not influence the data. Regardless, pockets should be emptied of coins, knives, etc., and wristwatches removed. Small amounts of metal such as wire-rimmed glasses, earrings, etc. are not detectable by the instrument, and are distant enough in normal use that they cannot cause problems. Steel-toed boots can have a profound impact on data. Steel shanks commonly found in boots are less problematic than steel toes, but should be avoided as the feet may closely approach the coils during data collection. The high sensitivity of the EM61 Hand-Held coils increases the likelihood that metal components in footwear may compromise data quality. Carefully inspect the operator for metal. Removing metal from the operator is most critical when operating the EM61 in harness mode because the operator is inside the coils.

b. The operating manuals of most geophysical instruments do not include a discussion of a warm-up period prior to collecting data. However, all geophysical instruments undergo a short period of calibration drift as the system electronics warm-up. Instruments should be allowed to warm-up a minimum of 5-15 minutes every time they are turned on or the battery is changed. Low ambient temperatures will demand a longer warm-up period. The geophysical team will carefully examine the readings to ensure that they have stabilized.

(1) Figure 6.1 illustrates drift typically seen in the warm-up period for an EM61. Performing a static test will quantify this warm-up calibration drift and at the same time satisfy the need to document ambient noise at the site. The static test shown in Figure 6.1 exhibits very low background noise. In this example, a standard EM61 was operated in Auto Mode (extra fast), collecting approximately 8 readings / second.

The ambient temperature was approximately 70 degrees F. The instrument electronics warmed up and produced stable readings in less than three minutes.

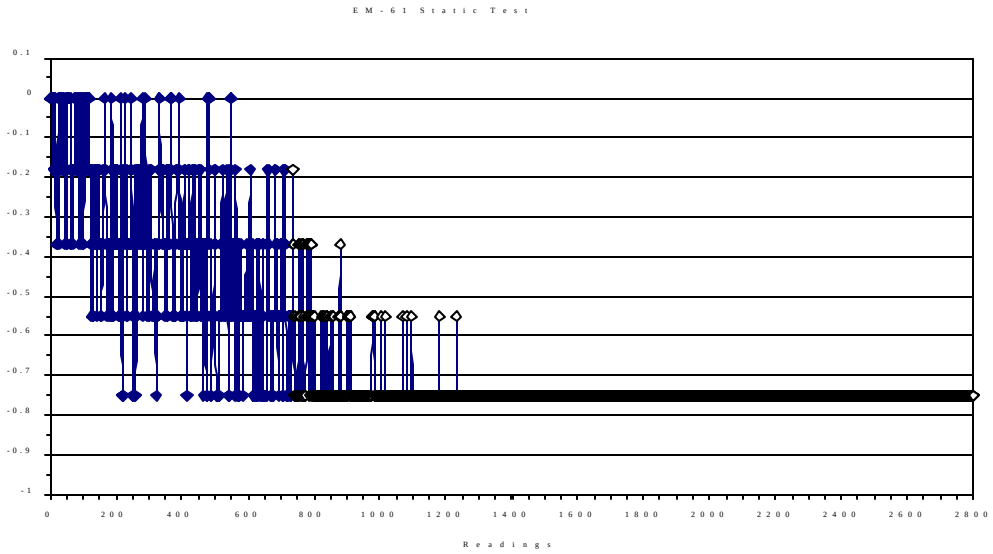


Figure 6.1 Battery Decay

c. Check battery levels and record in field notebook or grid survey form before and after data collection. EM61 batteries should be replaced when the voltage falls to 10.5 volts.

d. The rates of data acquisition for EM61's are limited by the processing speed of the data logging system. A minimum amount of time is required for the system to process and record each reading. If a second reading is triggered before the first is recorded, the data logger (polycorder) will 'beep' and the first reading will be dropped. This results in an incomplete data set.

(1) Using the standard EM61 or EM61 Hand-Held in Wheel or Hip Chain mode, the options of Full, Partial, or No Display are available at the start of each file. The Full option will display data after conversion to millivolts and allows the collection of 4 readings per second. The Partial setting displays data as unconverted raw voltage, allowing a collection rate of 8 readings per second. No Display shows only the present station coordinates, resulting in available collection rates of 8 readings per second.

(2) When starting a new file, a standard EM61or EM61 Hand-Held in Auto Mode offers the options of User Defined / Fast /Extra Fast data collection rates. The User Defined option is capable of recording up to 4 readings/second. The Fast option records 5 readings/second without GPS and 4 readings/second with a GPS time stamp. The Extra Fast mode collects 8 readings/second without GPS and 7 readings/second with a GPS time stamp.

(3) The EM61 MK2 uses a more sophisticated Juniper Systems Pro 4000 or Allegro field PC. The maximum data acquisition rate increases to 19 records/second, with each record consisting of four sampled time gates per station and, optionally, position data.

e. Older EM61 wheels contain a limited amount of metal that is distributed unevenly within the rim of the wheel. As a result, these wheels can cause periodic anomalous responses of several millivolts or more as measured by the bottom coil. With a low enough target selection threshold, the wheel responses may be incorrectly interpreted as being representative of subsurface metal.

(1) Alternatives to using the older hard rubber EM61wheels include substituting either EM61 Handheld wheels or the most recent standard EM61-MK2 wheels which have solid foam tires. Both types of wheels are free of any metal components and can be easily mounted on the EM61 axles.

(2) In addition to metal components in the wheels themselves, wheel noise can be introduced by nails or metal fragments embedded in the tires. This may also cause periodic anomalous responses as the object rotates past the coils. EM61-MK2 wheels will be carefully inspected throughout the data collection process in order to minimize this problem.

(3) Should wheel noise be suspected during the project, the following test can be performed. Invert the EM61-MK2 and conduct a static test for one minute followed by collecting one minute of data while slowly spinning each wheel. Any additional noise present in the portion of the file collected while a wheel was spinning is likely due to the presence of metal somewhere in that wheel.

f. Loose, dangling cables could potentially cause anomalous responses in EM61-MK2 data. The cable connecting the coils to the backpack should be temporarily attached to the handle (with tape, Velcro straps, etc.) in order to eliminate the cable as a source of geophysical noise.

g. At the start of every project, the geophysical consultant will establish a nulling station where the top and bottom coils can be leveled. The nulling station must be established in an area free of metal, with no interference from sources of ambient noise. Mark the center of the nulling station with a semi-permanent, non-metallic marker, to ensure consistent placement of the instrument each day. The station should be placed in the same spot as the static test station and will also be occupied at the beginning and end of each work day. Early model EM61s have no means for nulling, therefore data must be leveled during post-processing.

h. If GPS is to be used and logged to a separate recorder from that of the EM data, synchronization of the internal clocks is critical for accurate location of data. Once the clocks are synchronized, data collection may begin. It is recommend that you open a test/calibration data file in both data loggers and attempt to begin taking actual measurements at exactly the same time. It is recommended that this be completed at the start and end of each day as the clock in some DL600s is known to drift. (<1sec/24hours). This will get you to sub-second accuracy depending on how fast your fingers are. Additionally a known calibration "site" where a known EM target exists (such as a 6" spike driven into the ground) should be established. Locate the station accurately with the DPGS, and then collect data across the target a number of times in the same fashion, as you would be conducting your survey. It then becomes a simple spread sheet task to match the peak instrument response and time with the DPGS known target location. This information is then used in the DAT61W program.

i. During data acquisition, the operator will pay close attention to sounds emitted by EM61/MK2 backpack and the data logger to evaluate instrument function and data quality. Continuous, audible response may be indicative of metal stuck to the instrument (as in the case of barbed wire caught on the coils) or the effect of a low battery. No

audible response over visible metal objects may indicate another sort of instrument malfunction.

j. The operator will, when observed, note the presence of all sources of potential EM interference (objects that will affect the instruments response). These comments should be noted digitally on the instruments datalogger. The EM61/EM61-MK2 data acquisition systems allow for comments to be embedded in the data; thereby the correct position of the surface metal (or other source of interference) can be noted on the interpretation diagrams.

k. After data collection is completed, the consultant should recollect some data in order to demonstrate the consistency of the method.

Chapter 7 Navigation

7.1 Introduction.

Prior to the advent of GPS and other electronic navigation systems, geophysical data was collected and positioned using local coordinate systems. In recent years, GPS in particular has become an increasingly popular tool for geophysical surveys at buried munitions sites. The latest systems are capable of providing, under the right circumstances, positional accuracy measured in centimeters. Despite this, the use of local grids and conventional methods is still preferred in many circumstances, as it provides a high degree of accuracy at low cost, regardless of obstructions such as overhead tree canopy.

7.2 Conventional Navigation

These methods involve placing temporary markers on the ground surface in order to establish data collection lines. In a typical grid layout, the markers allow the operator to traverse the grid using straight, parallel lines and ensure that the entire area has been covered.

a. Grid set-up begins with the establishment of line separation and length in the required units (meters or feet). If squared grid corner stakes are already in place, tape measures can be pulled between them on all sides. Tape measures and/or surveying equipment (transit, compass, etc.) can be used to establish right angles if no grid stakes are present.

b. Fiducial marks (known locations entered into the data during collection) will be placed on the ground using temporary markers. Temporary markers commonly used for fiducial locations include measuring tapes, marking paint and ropes. The distance between fiducial marks is dictated by site conditions; less visibility due to rolling terrain or dense vegetation will require closer spacing.

c. Using conventional navigation methods, it is essential that straight-line profiling be maintained. The operator must have easily visible monuments along which to walk. Fiducial ropes with paint marks at every line location will accomplish this. Another

commonly used method is to place traffic cones at the start, end and at intervals along each line. The use of cones requires the operator or other team members to move them as data collection proceeds.

7.3 Global Positioning System (GPS)

This method of navigation has increased in popularity in recent years, as the accuracy of the positions has increased. Software for most geophysical systems now includes a means of integrating GPS positions with geophysical data.

a. Standards for Equipment: GPS equipment varies drastically in price and quality, therefore a minimum standard for equipment to be used in Digital Geophysical Mapping (DGM) surveys must be defined.

   (1) Small hand-held units manufactured for recreational use are not acceptable for DGM work. These units typically cost $150 to $400, and while helpful for finding general locations, are not capable of the level of precision necessary for geophysical surveying. While Selective Availability (SA) is not in use by the Department of Defense, these types of GPS units can achieve accuracies of approximately 30 meters. With SA activated, accuracy drops to approximately 100 meters.

   (2) The use of Differential GPS (DGPS) allows for the correction of errors in positioning from SA and other sources, which include clock errors, atmospheric effects, and signal reflections. Accuracies within a meter or two are possible using DGPS, given favorable conditions. Differential GPS making use of the Carrier Phase permits accuracies within centimeters. Correction of bias factors may be accomplished in real time, using a Real Time Kinematic (RTK) GPS system, or through Post Processing. RTK systems utilize a base station, set up on a known point, which then transmits corrections to a roving GPS unit via radio. Post Processing techniques also rely on base stations, which can be set up on site, or can be a remote station. Base station data is used to apply a correction vector to the rover data. The level of accuracy required for a specific project depends on the goals.

b. Minimum Standards for Data Quality: The number and location of satellites visible to the antenna, and the presence of obstructions influence the level of accuracy for a GPS reading.

(1) A factor called DOP (dilution of precision) is a measure of the level of precision that can be expected for a particular arrangement of satellites. The DOP is computed from a number of other factors, including: HDOP (horizontal), VDOP (vertical), TDOP (time). Together these factors are used to compute the PDOP (position dilution of precision). Although PDOP is commonly used, HDOP may be more applicable to DGM work, in which the x,y coordinates are used to map anomalies. GPS accuracy in the vertical dimension is less than in the horizontal. Most GPS receivers can be programmed to output the HDOP or PDOP, which is reported as a number between 1 and 9. For HDOP, a value of 1 is ideal, 2 is considered excellent, 3 to 5 good, 6 to 8 fair, and 9 poor. A maximum value of 5 is recommended for DGM surveys.

(2) Although PDOP (or HDOP) gives some indication of data quality, probably the most important indicator of data quality is the number of satellites used for determining position. It is possible to have a low PDOP and still have significant errors in positioning, especially with few satellites. A minimum of four satellites is needed to determine position; however accuracy increases with additional satellites. For DGM surveys, a minimum of 5 satellites should be used at all times for GPS data collection.

c. Time Synchronization: GPS satellites use atomic clocks capable of extremely accurate time keeping. Geophysical instruments use somewhat less sophisticated clocks, which may drift in relation to the GPS clocks. When recording geophysical data in a separate device from the GPS data, the recorded times are used to later position the readings. It is crucial that the times be synchronized to permit accurate location of the data. Prior to collecting data, the times must be synchronized between the two devices as accurately as possible. When finishing a grid, transect, etc, check the synchronization of the data recorders again, and record any difference noted. The difference will be used to apply a correction to the data.

d. Quality Control: A point will be established on the site where GPS readings will be collected twice daily (AM and PM), for comparison of the computed position. This point will be located in a convenient area, such as the nulling station.

e. Planning Software: Software is available from the major manufacturers of GPS equipment for planning surveys ahead of time. The orbits of the satellites, and the time they will pass over a specific area is included in GPS almanacs, which are downloaded from the satellites by the GPS receiver or may be downloaded from the Internet. The planning software uses this information to determine the number of satellites and predicted PDOP for a given location and date. At certain times of day, the number of satellites visible to the receiver may be inadequate to provide high quality data. Another possibility is that the constellation geometry may be such that a high PDOP results. In either case, knowledge of this period ahead of time will prevent the consultant from attempting to collect data with poor precision. Work / Rest periods must be planned to avoid data collection in times of poor satellite geometry or few visible satellites.

7.4 Other Positioning Systems.

A number of other types of positioning systems have been employed in geophysical surveys, or are currently in development. These other systems include Ultrasonic Positioning, which makes use of an ultrasonic transmitter and a series of stationary receivers to calculate the position of the instrument. Laser Distancing and Robotic Total Stations are other possible navigation systems for positioning data. One method currently under development makes use of time-modulated ultra-wideband (TM-UWB) communications. This system will utilize radios for positioning, with local transmitters on a site. Unlike GPS, the system will be unaffected by dense vegetation and overhead canopy.

7.5 Data Documentation

All positional data collected using GPS or other methods should have an ASCII describing the properties and attributes of the data set. A “readme” text (.txt) file should be prepared and submitted documenting the following information:

Name of Company, Address of Company, Phone Number of Company, name of Operator, E-mail address of Operator, Date Data collected, Model of Navigation Equipment: Serial Numbers of Receivers, and Antennas, Base Station(s) used in differential correction, Accuracy of system (according to manufacturer), Software used for data download and differential corrections.

Chapter 8 Data Storage and Transfer

8.1 Recommended Field Storage and Transfer Procedures.

a. Instrument data will be dumped from the polycorder, PRO4000 or Allegro to a field computer immediately following completion of a survey grid. If the data logger does not have sufficient memory to complete an entire grid, it will be dumped as needed. Immediate dumping lowers the risk of any data being lost as well as allowing the consultant to make initial assessments regarding data quality and methodology.

b. The consultant will create a logical system of directories for storage of raw and edited geophysical data and positional data. The specific design of this system shall be left up to the consultant, but each consultant should adopt one system that can be used on all OE projects.

c. Each day the consultant will perform a backup of all new data files. Appropriate backup media include, but are not limited to, 3.5" diskettes, Zip disks, and CD-ROMs.

d. If possible, new data will be transferred electronically to the consultant's corporate office on a daily basis. The transfer may be accomplished via E-mail or using an FTP site. If neither of these options is logistically feasible, data will be shipped to the consultant's office on appropriate media as scheduling permits.

e. The field geophysical team will fill out a Geophysical Survey Daily Log each day.

8.2 Checklist for Data Transfer and Storage.

Project Name: _____

Project Location: _____

Design Center POC: _____

Reviewer's Name and Title: _____

Date of Review: _____

	Y	N	N/A
f. Have all of the following been included in the transfer packet:			
• Raw data files?	____	____	____
• Edited data files?	____	____	____
• GPS positioning files (if separate)?	____	____	____
• Completed geophysical maps?	____	____	____
• Prioritized target lists?			
• "ReadMe" file detailing contents?			

Chapter 9 Data Processing and Analysis

9.1 Introduction

This chapter outlines basic data processing procedures for geophysical data collected for buried munitions surveys. Systematic and proven methods are important to maintain consistent quality of data and to allow for an evaluation of data quality. Identifying and reducing the causes of below standard data is simplified by following a basic established method.

Qualified personnel for data collection and data processing are the most important factors in producing quality data. Data collection personnel should be trained and familiar with the instruments and their operation. Data processing personnel must have an understanding of the geophysical principles and the nature of the data in order to properly evaluate the sensor response. A qualified geophysicist must be able to identify and correct for noise factors and be able to distinguish signals above the noise level. Inexperienced personnel may result in a reduction of the quality or incorrect interpretation of data. The main stages of geophysical data processing and analysis for buried munitions are field editing, preprocessing, processing and target selection, advanced processing, and the preparation of deliverables.

9.2 Field Editing Data

These steps are performed prior to leaving the site by the field geophysicist or a data processor on site.

a. The software supplied with most geophysical instruments allows the editing of many of the common errors made during data acquisition. A member of the geophysical team, preferably the operator who collected the data, will evaluate the completed file for correctness of line numbers, starting and ending points, and line direction. Fiducial corrections will then be applied to the data. All editing and corrections will then be saved using a new file name.

b. Each line's response amplitude will be examined in profile for overall quality. Particular attention will be paid to geophysical noise levels to ensure that they fall within acceptable

thresholds. Acceptable noise levels vary from site to site and should be agreed upon based on the collected data.

c. Geophysical sensors will occasionally exhibit drop-outs or spikes; extremely high or low values. Anomalous values believed to be drop-outs or spikes should be removed from the data set as they are not representative of responses to subsurface metal. Frequent occurrences may be indicative of a malfunctioning instrument that should be thoroughly tested and possibly replaced.

d. Metal inadvertently worn by the operator is one of the most common sources of geophysical noise. If unacceptable levels of noise are noted in the data, the possibility of metal on the operator shall immediately be evaluated.

e. Once the data file has been edited and checked for quality, it must be converted to a xyz file format for contouring and examination. The most common programs used to contour geophysical data, Golden's Surfer and Geosoft's Oasis Montaj, accept xyz files. Such files can also be viewed as Microsoft Excel spreadsheets. If alternate file formats will be required, this should be made known to the consultant prior to the start of the project.

f. After the data values have been examined and determined to be of high quality, the positioning of the data must be evaluated. Regardless of whether electronic or conventional navigation methods are used, the process for checking accuracy is the same. Most common contouring programs allow the creation of post maps. These maps show the geographic position of every point collected. The lines and stations should be evenly spaced throughout a grid. Problems in data spacing using conventional navigation methods are usually caused by misplaced fiducial marks or end points and can be easily remedied. Data positioning errors found in electronic navigation can be caused by a variety of problems and are often more difficult to fix.

g. Fill out Field Editing Checklist (example included at end of Chapter 9) to track procedures performed on data set.

9.3 Preprocessing

These corrections are applied to the raw data to improve positioning and remove any other errors introduced by the instrument.

a. Incorporating navigation information. Positioning geophysical data and conversion to required coordinate system. When positioning data is stored in a separate file from sensor data, e.g. GPS, a common marker such as a time stamp is required in both data sets to correctly position the sensor data. This step should also include the interpolation of positions if required and any conversion or projection to a specified coordinate system.

b. Removal of Instrument Drift and Leveling of Data. Drift correction is needed when the "no response" value of an instrument changes during the course of the survey. This can be caused by temperature variations and may be minimized by allowing the instrument to warm up for a sufficient amount of time before use. Leveling may be performed manually by visual inspection of the data or statistically by calculating the deviation of the data from the mean or "no response" value.

c. Lag (and Offset) Corrections. Lag effects are visible in gridded data as chevron patterns or wavy edges of anomalies, see Figure 9.1. Lag is caused by a time delay in instrument response and the recorded position. Determining the shift is done by measuring the distance between equivalent points of an anomaly on neighboring lines and dividing this value by two. A negative lag will shift the data forward in time (for the sensor trailing the logger) and a positive lag shifts the data back in time (for a sensor leading the logger).

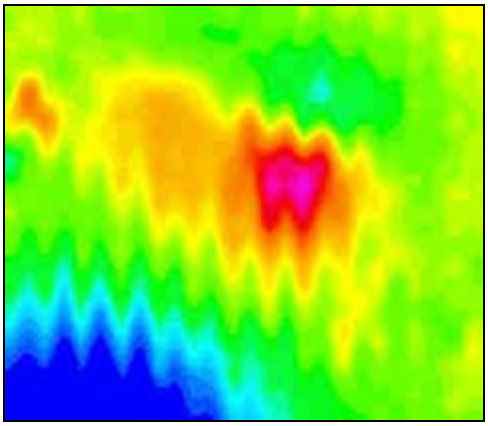


Figure 9.1 Example of Chevron Affect

9.4 Processing and Target Selection

This section describes the application of processing routines and filters, analysis of geophysical data and interpretation of gridded or modeled data. When using filters it is important to keep their limitations in mind. Inappropriate usage can result in the removal or corruption of real anomalies, accentuation of noise or ringing, and add errors to the data. An understanding of the effects of filtering is necessary.

a. Gridding and Contouring. Preprocessed data is gridded and contoured to create a smooth interpolated 3D response plot of the area. Gridding method and parameters should be selected to best preserve the true nature of the collected data.

b. Digital Filtering and Enhancement. Data is filtered and enhanced to diminish the effects of noise and enhance the anomalous response and subsequent re-gridding if required. The following list describes some of the more common filters used for geophysical data.

(1) Linear low pass - removes high frequency, short wavelength features from the data. This filter is effective at removing low amplitude high frequency noise and tends to smooth the signal.

(2) Linear high pass - removes low frequency, long wavelength features from the data. The result will be the sharpening of features in the data.

(3) Linear band pass - is a combination of a high and a low pass filter allowing only features with wavelengths between a specified long and short wavelength to remain in the data.

(4) Non-linear - a de-spiking algorithm effective at removing short wavelength features with high amplitudes from the signal. Filter tolerances are set for the width and amplitude of spikes to reject relative to the local background. Once rejected features are removed they can be replaced by interpolated values based on neighboring readings.

(5) Rolling statistics - calculates the statistics within a moving window along a channel of data. This filter will produce a statistical measure of the data within the moving

window and outputs the selected statistical value at the center of the window. This filter can be used as a measure of the variability of the data or as a means to smooth out the appearance of the data.

(6) Difference - useful for identifying noise in data. A difference filter calculates the difference between values in a single channel of data; the fourth difference filter is the most common.

(7) 3x3 Hanning convolution - this smoothing filter tends to reduce low amplitude, high frequency responses within the data. It also improves the appearance of the gridded data by soothing transitions between contours. The overall effect of the Hanning filter is a reduction in the number of peaks within a grid.

d. Threshold Selection. Generally a single threshold is set for an entire site. The selection of the threshold value should be based upon two main factors:

(1) It should be set above the apparent noise level of the data set.

(2) It should be set below the expected response amplitude of buried munition items on the site.

e. Anomaly Selection and Quality Control of Target Picks. A peak-picking algorithm is performed on gridded data to identify anomalies with positive responses above a selected threshold. Any automated target selections must be reviewed by a qualified geophysicist and refined; missed targets should be added and redundant picks removed. If necessary, identify areas or regions that have high ferrous or geologic clutter as it may not be practical to perform discrete target selection within these regions.

f. Prioritization of selected targets. Targets are usually prioritized by amplitude (including analytic signal) and assigned unique target identifiers for each selected anomaly.

9.5 Advanced Processing

Advanced processing involves further steps beyond target selection to prioritize and discriminate selected targets. The items listed below should be regarded as a brief list of the more established advanced processing topics currently being used and developed. There is considerable research being conducted in the buried munitions discrimination field and although some new methods are producing positive results it is not possible to include a complete list of all developmental processing techniques.

a. Depth Estimates. The Geonics depth calculations are as follows:

$$\mathbf{d} = -2229.57 + (7288.13 \bullet \mathbf{R}) - (9635.78 \bullet \mathbf{R}^2) + (6458.69 \bullet \mathbf{R}^3) - (2158.63 \bullet \mathbf{R}^4) + (292.118 \bullet \mathbf{R}^5)$$

Equation 9.1 Geonics Depth Calculation for 1 x 1 meter system

d is in centimeters

R is the ratio $\frac{TopCoil}{BottomCoil}$

$$\mathbf{d} = -155.95 + (795.09 \bullet \mathbf{R}) - (1715.82 \bullet \mathbf{R}^2) + (2026.38 \bullet \mathbf{R}^3) - (1413.19 \bullet \mathbf{R}^4) + (582.55 \bullet \mathbf{R}^5)$$

Equation 9.2 Geonics Depth Calculation for 1 x 0.5 meter system

d is in centimeters

R is the ratio $\frac{TopCoil}{BottomCoil}$

b. Analysis of Spatial Anomaly Shape. This is used to distinguish between intact ordnance and clutter.

c. Multi-channel Analysis, e.g. Time Decay Curve or Amplitude and Phase Response. Developing systems such as the Geonics EM-63 have shown that different ordnance items have unique responses when viewed over multiple time gates. Currently algorithms are being developed to discriminate different ordnance with this instrument.

d. Merging of Multi-sensor Data. For example magnetic and electromagnetic data collected over the same site will have the advantages. The combination of these two data sets can provide relatively accurate depth estimates from the EM data as well as size and weight

estimates from the magnetic data. By comparing selected EM and magnetic anomalies, classifications such as ferrous/non-ferrous/magnetic rock can be made.

9.6 Data Presentation/Deliverables

The results of the geophysical investigation should be submitted as follows.

a. Dig list (in ASCII or Excel format), see Figure 9.2, of selected targets with the target location given in the referenced coordinate system, represented amplitude of response based on selection criteria, and any comments or details regarding target properties.

Client
Site/Grid
Project Name
Instrument
Location
Date of Survey

Selected Target Pick Table (Instrument)

Unique Target ID	Grid Target ID	State Plane Coordinates (zone and units info)		Local Grid Coordinates (units)		Peak Response (units)	Comments
		X (East)	Y (North)	x	y		
C5-1	1	1763925.07	3605802.39	34.95	91.97	33.20	
C5-2	2	1763989.09	3605754.39	54.00	14.25	25.86	
C5-3	3	1763922.13	3605788.70	24.00	83.25	21.73	

Figure 9.2 Example Dig Sheet

b. Maps will include all the following basic map features in addition to any other necessary site information.

(1) Title block containing client, instrument and type of data (component), site/grid, site name and location, date of survey. Other information that could be included: date of processing, processor, consultant, etc.

(2) Scale displayed and one or combination of graphical/bar, or representative fraction scale. Appropriate choice of scale is advisable with reasonable metric ratio scales as 1: multiples of 25, 100, 250, 1000, 2500, etc. and reasonable English ratio scales as 1: multiples of 12, 18, 120, 180, 1200, 1800, etc. Scale selection should result in a map

that is large enough to show all relevant detail and still be a manageable size when produced in hard copy.

(3) A north arrow indicating either true north or grid north if presented in local coordinates and additional site information showing the relationship between true and grid north.

(4) Contour interval indicator. A color scale bar indicating represented color contour intervals for 2D color display, description of line contour intervals for 2D line contour display, or vertical scale statement for simulated 3D mesh display.

(5) Sources of EM interference noted during the data collection plotted spatially and appropriately identified in the legend.

(6) For submittals the consultant will provide maps in editable form (if available, e.g. Geosoft .map or Surfer .plt formats) and map images in a common image format, such as JPEG, for viewing without the software used to produce the maps.

c. Geophysical maps, see Figure 9.3, should be large-scale maps containing all the basic map features and the gridded data displayed with color and/or line contours and target symbols.

d. Site maps showing the location of the data and relevant cultural features in addition to the basic map features. Often cultural features can cause a response in the geophysical data. Fixed location features are also useful for relocating grids established with a local coordinate system.

e. Additional site information to support mapping should be provided if available.

(1) Details of several methods of positioning using site information can be used. If a local grid system is used, culture maps created in the field during data acquisition noting the location of cultural features with reference to the local grid coordinates must be included.

(2) Additional GPS data to identify points or features of interest. If GPS is used to shoot in points and/or boundaries of cultur al features this can be presented with gridded RTK GPS geophysical data.

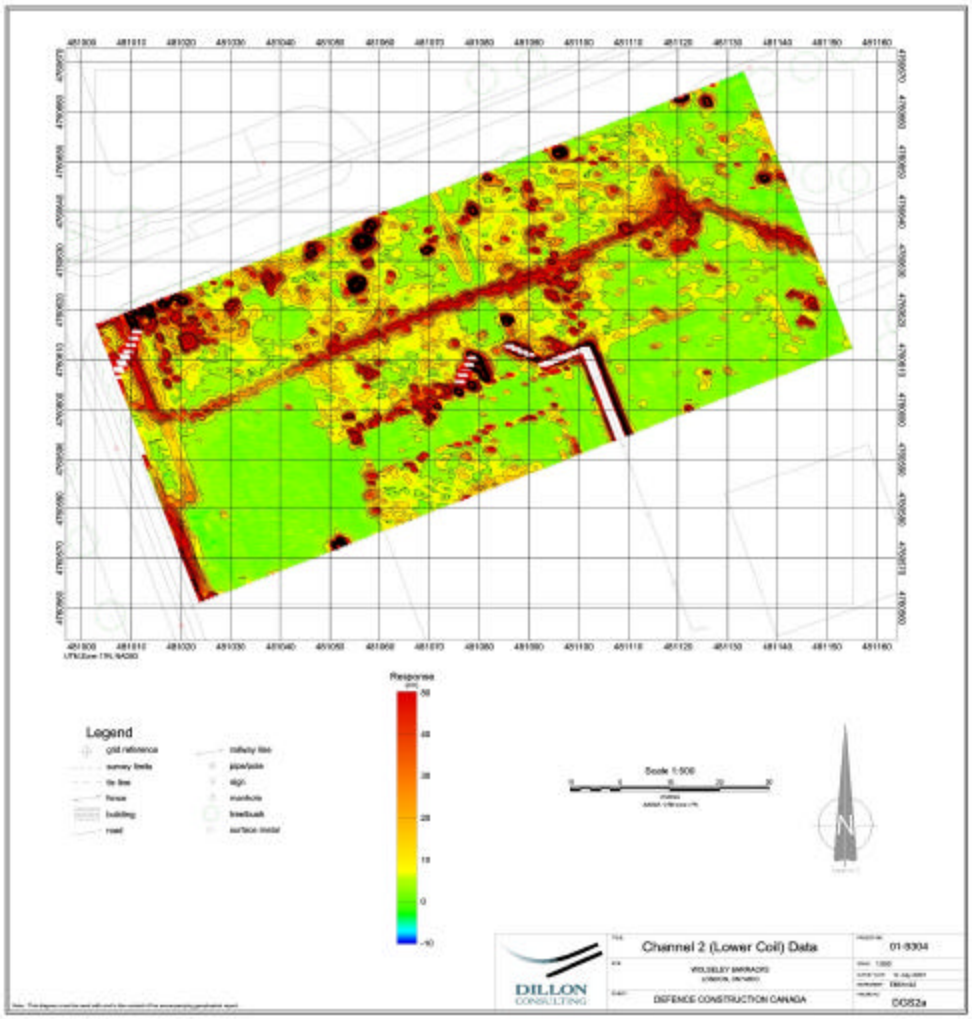


Figure 9.3 Sample Diagram

Example of a geophysical map containing basic map features and geophysical data.

(3) Geo-referenced aerial photographs of the site can be presented or superimposed with geophysical data when positioned with GPS or surveyed corners. Broad scale surface features can sometimes be matched with geophysical anomalies, combining two highly informative visual representations of the site.

(4) Known cultural features with anomalous responses in the geophysical data should be marked out on the maps or noted within the accompanying report text.

(5) Presentation of digital elevation models.

(6) Additional geologic information or geophysical data collected using other methods. This information is useful for broad scale interpretation of data collected at buried munitions sites. Geologic background responses may be visible in the geophysical data and are more easily identified with additional site information.

9.7 Checklist for Field Editing

Project Name: _____

Project Location: _____

Design Center POC: _____

Reviewer's Name and Title: _____

Date of Review: _____

	Y	N	N/A
a. Have the following items been evaluated for correctness and edited if necessary:			
• Line numbers?	____	____	____
• Start and end points?	____	____	____
• Line direction?	____	____	____
• Fiducial locations?	____	____	____
b. Has the data been examined in profile and evaluated for geophysical noise?	____	____	____
c. Has the data been examined for the presence of drop-outs and spikes?	____	____	____
d. Has the presence of metal on the operator been eliminated as a possible source of geophysical noise?	____	____	____
e. Has the edited data been converted to the appropriate .xyz format?	____	____	____
f. Has the positional data been evaluated for accuracy and completeness?	____	____	____

9.8 Checklist for Data Processing

			FILENAMES:
Site:	_____	Raw:	_____
Location:	_____	Edited:	_____
Consultant:	_____	Processed:	_____
Sector:	_____	Contour Map:	_____
Grid:	_____	Target List:	_____
Processor(s):	_____	Target Map:	_____

	Y	N	N/A
Preprocessing			
a. Coordinate Conversion			
Projected Coordinate System _____	____	____	____
b. Removal of Drift and Leveling	____	____	____
c. Lag and Offset	____	____	____
Processing			
a. Initial Gridding	____	____	____
b. Calculation of 3D Analytic Signal	____	____	____
c. Digital Filtering and Enhancement			
❑ Low Pass			
❑ High Pass			
❑ Non Linear	____	____	____
❑ 3x3 Convolution			
❑ Difference			
❑ Other _____			
d. Threshold Selection			
Threshold value _____	____	____	____
e. Anomaly Selection			
Number of targets _____	____	____	____

	Y	N	N/A
Advanced Processing			
a. Depth Estimates	____	____	____
b. Analysis of Spatial Anomaly Shape, Response Tensor and Aspect Ratio	____	____	____
c. Multi Channel Analysis	____	____	____
d. Merging of Multi Sensor Data	____	____	____
Data Presentation			
a. Target and Dig Lists	____	____	____
b. Geophysical Maps	____	____	____
c. Site Maps	____	____	____
d. Additional Information			
❑ Additional Information on Positioning ❑ Culture Maps/Features ❑ Additional GPS Point Features or Boundaries ❑ Geo-referenced Aerial Photographs ❑ Digital Elevation Models ❑ Additional Geophysical Data or Geologic Information ❑ Other _____	____	____	____

Chapter 10 Anomaly Location and Marking

10.1 Introduction

a. Accurate reacquisition and marking of targets selected for excavation is critical to the success of a geophysical survey. The objective of target reacquisition is to mark on the ground the location of each target, with adequate precision to minimize the size of the excavation and time required to remove the target. The two primary elements of reacquisition are: locating and marking the interpreted x,y target locations from the dig list, and adjusting marked locations to improve their precision.

b. It is imperative that the DGM consultant responsible for the original data acquisition maintains the responsibility chain by performing all aspects of target reacquisition. The best results can only be obtained by those who are most familiar with the survey procedures and navigational methods utilized during data collection. In the best case the same personnel originally acquiring the data perform the reacquisition. The following are procedures for target reacquisition with discussions on methodologies and techniques.

10.2 Marking Interpreted Target Locations

a. The first step in successfully reacquiring targets for excavation is to survey and mark the locations as interpreted from the geophysical survey data. The consultant shall utilize the same navigational methods and techniques as were used during the original investigation. Resurveying the x,y target locations in this manner is vital to accurate reacquisition. For example, due to terrain characteristics, problems are often encountered when interchanging Global Positioning System (GPS) and traditional tape measure surveying methods. Target locations are to be marked in the field using non-metallic pin flags. Each flag will be labeled with a target identification number so that the status of each

anomaly can be tracked and documented through reacquisition, excavation, and final QC procedures.

10.3 Challenges in Re-locating Targets

a. After marking target locations interpreted from original survey data, the opportunity exists to improve upon those locations through further, detailed geophysical investigation. Using geophysical instrumentation to acquire the actual peak of an anomaly, the interpreted location can be refined. The consultant must use the same geophysical instrumentation as during the original survey, for several reasons.

(1) To permit the reacquired target amplitude to be compared to the original amplitude. By comparing amplitudes the team can verify that the correct target has indeed been reacquired. Lower amplitude anomalies (below the selected threshold) may exist in close proximity to the target.

(2) Different instruments have different depth detection capabilities, and in some cases different capabilities for types of metal that can be detected. Aluminum targets identified by an electromagnetic instrument will not be detected by a magnetometer.

(3) Assuming the instrument(s) used for the original survey were selected with response (or lack of) to site-specific noise in mind, using the same instrumentation will avoid complications from noise elements during reacquisition.

b. The location of an anomaly's peak response, whether using magnetic or electromagnetic methods is not always directly over the target.

(1) EM: Responses are not always highest directly above the target item. Like the distorted primary fields measured by magnetic methods, the dimensions of secondary fields measured by EM instruments are rarely uniform. As a result, the peak responses are often located adjacent to the target's position. A

complication of the EM61 response is that peak responses may occur when the target item is located beneath an edge of the coil, rather than the center of the coil. This effect is frequently observed when the target a long, relatively small, horizontal and shallow. A profile over such a target produces a double-peak response as the front and back coil edges pass in close proximity to the shallow target.

(2) For reacquisition purposes, the peak response obtained by an EM instruments is considered to be the best measurable location of the target

Locate Targets

The Analytic Signal grid is used to pick targets because the peaks in the Analytic Signal grid are assumed to occur directly above the buried magnetic ordnance. The "Distance Units" would be the units of the grid.

No. of Passes of Smoothing Filter

The "No. of passes of smoothing filter" will apply a Hanning filter to the Analytic Signal grid so that low amplitude, high frequency "noise" targets (which could be instrument noise), will not be picked. The grid won't be smoothed if you enter zero or leave the entry blank. More filter passes tend to reduce the number of peaks found. The default is to apply the filter 3 times. The system applies the 9-point (3x3) Hanning smoothing filter to the grid, if smoothing is desired. The coefficients of the filter are:

0.06	0.10	0.06
0.10	0.36	0.10
0.06	0.10	0.06

Note: If your data isn't noisy then you don't need to do any smoothing to the data.

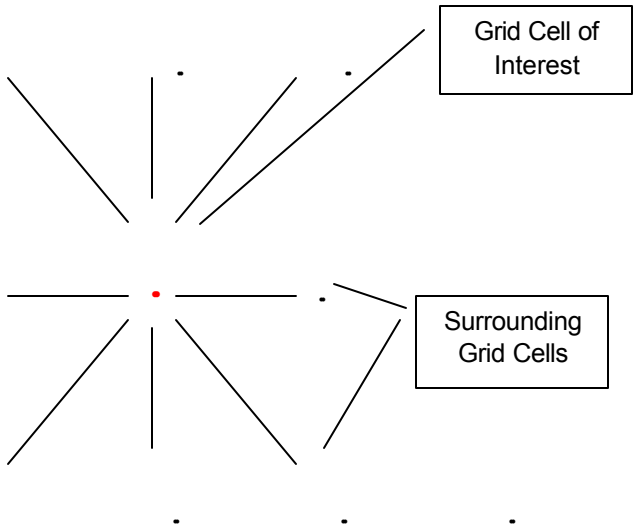
Level of Peak Detection:

The automated peak-picking algorithm, which is based on a technique by Blakely (1986), is used to find the location of individual peaks or both peaks and ridges in the Analytic Signal grid. The Blakely method looks at each grid cell to be considered and compares its value with the values of eight nearest grid cells in four directions (along the row, column, and both diagonals). The definition of what constitutes a peak can be controlled through the "Level of Peak-Detection" (Blakely index). You can increase or decrease the number of picked targets by decreasing or increasing the Blakely index:

Normal (4)	Grid values in all nearest grid cells are lower.
More peaks (3)	Grid values in any three directions are lower.
Even more peaks (2)	Grid values in any two directions are lower.
All ridge peaks (1)	Grid values in one direction are lower.

Note: You would generally want to use Normal (4) in most cases and therefore it is the default. However, selecting Normal (4) finds fewer peaks. To find all ridges, use All ridge peaks (1) option.

Pictorially, this method would look like:



Grid Value Cutoff Level:

The "Grid Value Cutoff Level" is really a threshold value that allows the user to enter a minimum amplitude so that Analytic Signal peaks below this level are excluded from the target list. The cut-off amplitude used should represent the detection limit of the measuring equipment, but will be very dependent on the local survey conditions (e.g. noise) due to ferrous "contaminants" such as nails and other pieces of scrap metals.

Initially you would want to set the "Grid Value Cutoff Level" to zero to see how many targets are picked. Unless your background is very smooth you will need to use a cutoff level. To pick a correct value, look at the amplitudes of the expected signal response.

Near-surface objects can always be windowed out later in the processing sequence once the depths of all the targets have been calculated.

In your data set I picked a grid cutoff level of 4mVolts – no hanning filter (0) and a normal level of peak detection.

Good luck
Quentin

Instruction Manual

Model GA-52C*x*

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Preface

The Model GA-52Cx Magnetic Locator is a product of over forty-five years of experience in producing the world's finest flux-gate magnetometers and magnetic detectors for aerospace, military and civilian applications. The GA-52Cx incorporates the knowledge obtained from manufacturing under the most rigid quality control standards. The heart of the GA-52Cx is its patented Schonstedt HeliFlux ® magnetic field sensors. These sensors, acknowledged to be the world's finest, make possible the unequaled performance of our locators.

June 2003

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Important Notice

Schonstedt believes the statements contained herein to be accurate and reliable. But their accuracy, reliability, or completeness is not guaranteed.

Schonstedt's only obligation shall be to repair or replace any instrument proved to be defective within seven years of purchase. Schonstedt shall not be responsible for any injury to persons or property, direct or consequential, arising from the use of any instrument.

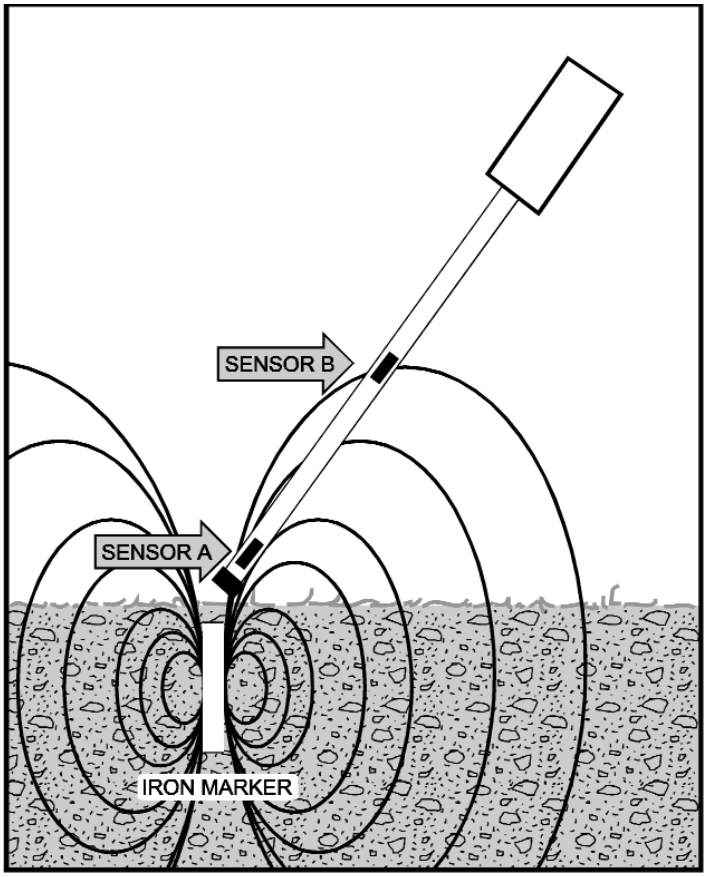
Operation

Introduction

The GA-52C*x* Magnetic Locator detects the magnetic field of a ferromagnetic object. It responds to the difference in the magnetic field between two sensors spaced about 20 inches apart. The response is a change in the frequency of the signal emitted by the piezoelectric speaker.

Figure 1 illustrates an application of the locator in which it is used to detect an iron marker of the type used for property line identification. As shown, the magnetic field of the iron marker is stronger at sensor **A** than it is at sensor **B**. As a result, the frequency from the piezo electric speaker is higher than the idling frequency, 40 Hz, which exists when the field strength is the same at both sensors.

Figure 1. Detecting Magnetic Field of an Iron Marker



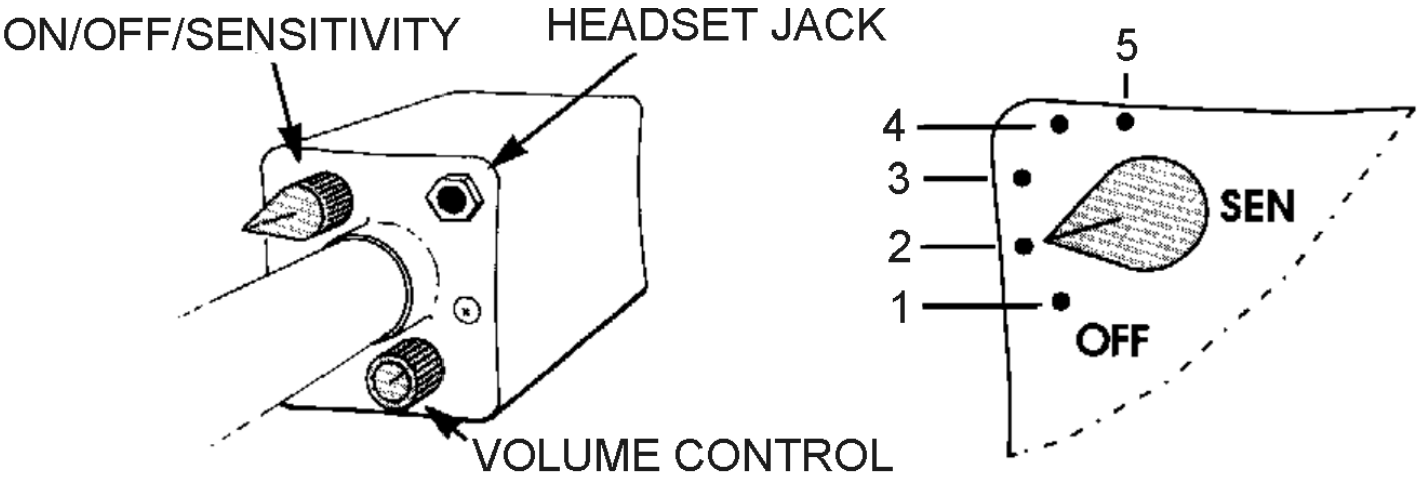
Turn-On, Sensitivity and Volume Settings

Set the On-Off/Sensitivity Control to position 2 and adjust the Volume control until the idling tone reaches a desired level. Setting the Sensitivity control to position 2 provides what is referred to as the "Normal Operating Range." Positions 3 to 5 increase the sensitivity; position 1 decreases the sensitivity.

The locator can be oriented in any direction without producing a significant change in the frequency of the tone from its idling frequency.

When using headphones the Volume Control has no affect on the output level of the audio signal.

Figure 2. Sensitivity Set for Normal Range (position 2)



Search Procedure

Set the sensitivity control to position 2 (Normal Range) and grasp the locator as illustrated. Because the upper sensor is located near where the locator is usually held, wrist watches may produce unwanted changes in the tones frequency. (Remove your wrist watch or hold the locator in the other hand). Keep the locator away from your shoes, since they might contain magnetic material.

To obtain maximum area coverage, the locator should be swept from side-to-side. When the locator comes within range of an object, you will hear an increase in the frequency of the output signal.

Figure 3. Searching with the locator

Application Notes

Basic Signal Patterns

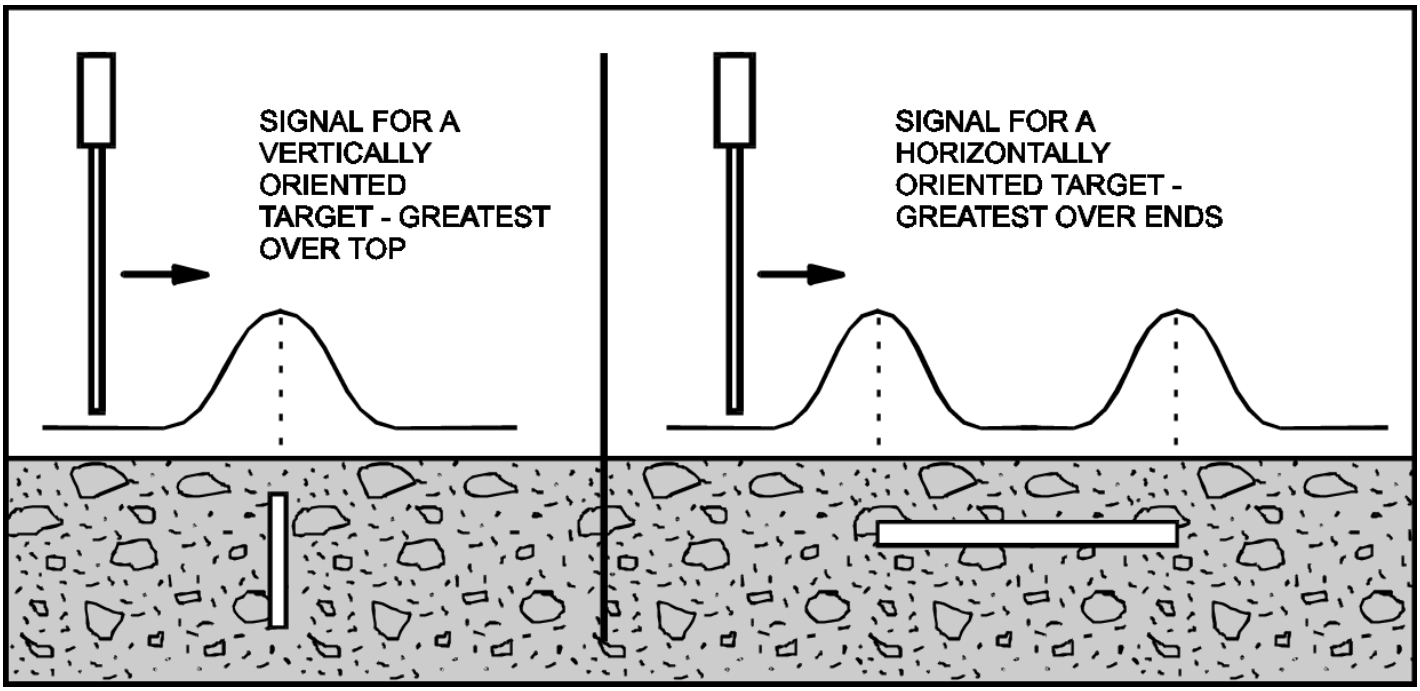


Figure 4. Signals from Vertical and Horizontal Targets

After you have detected the presence of a target, hold the locator vertically and move it back and forth in an "X" pattern. The peak signal occurs directly over a vertical target, and over the ends of a horizontal target.

The "X" pattern is ideal for pinpointing small objects. A 1-1/4-inch PK nail buried up to 12 inches can be located so precisely with this technique that it can be uncovered using a 1/2-inch star drill.

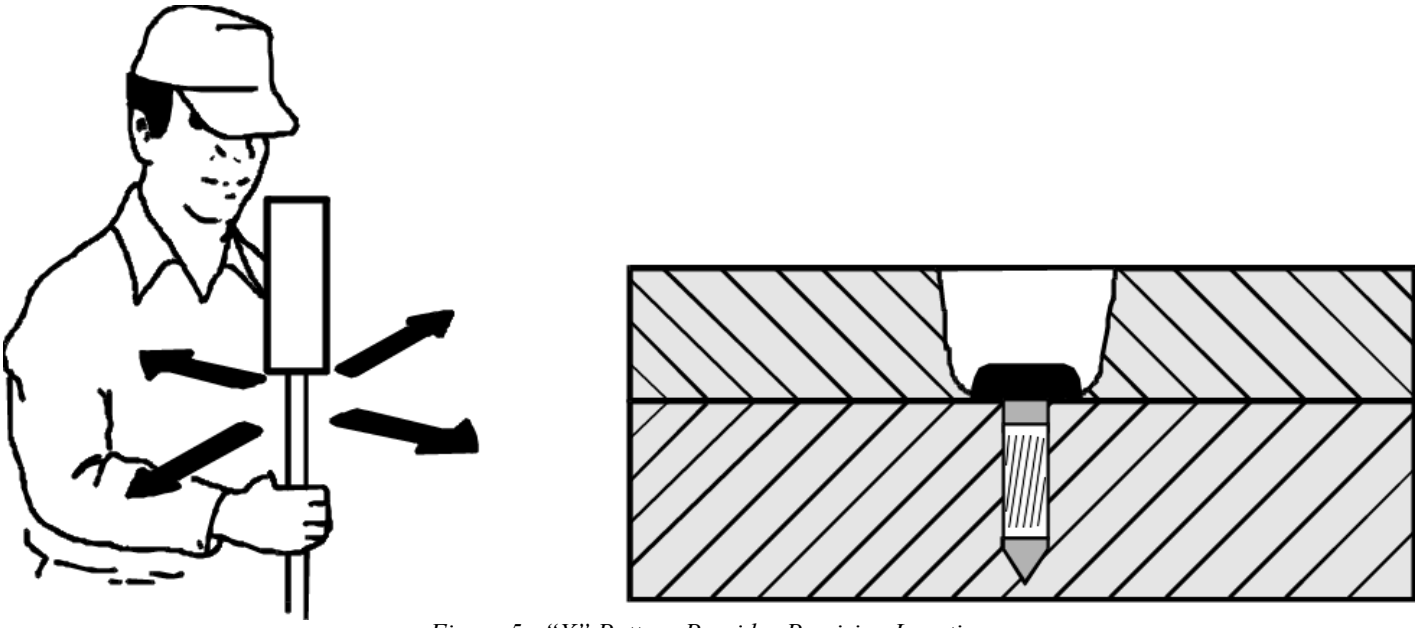


Figure 5. "X" Pattern Provides Precision Locating

If you find more than one signal in the vicinity of a target, just raise the locator several inches higher or reduce the sensitivity setting. Any signal that disappears when the locator is raised or the sensitivity is reduced is probably not coming from the actual target. The signal from a rusty bolt or other small item will decrease much faster with distance than the signal from a larger target such as a corner marker. An 18-inch length of 3/4-inch pipe can be located at depths up to 9 feet.

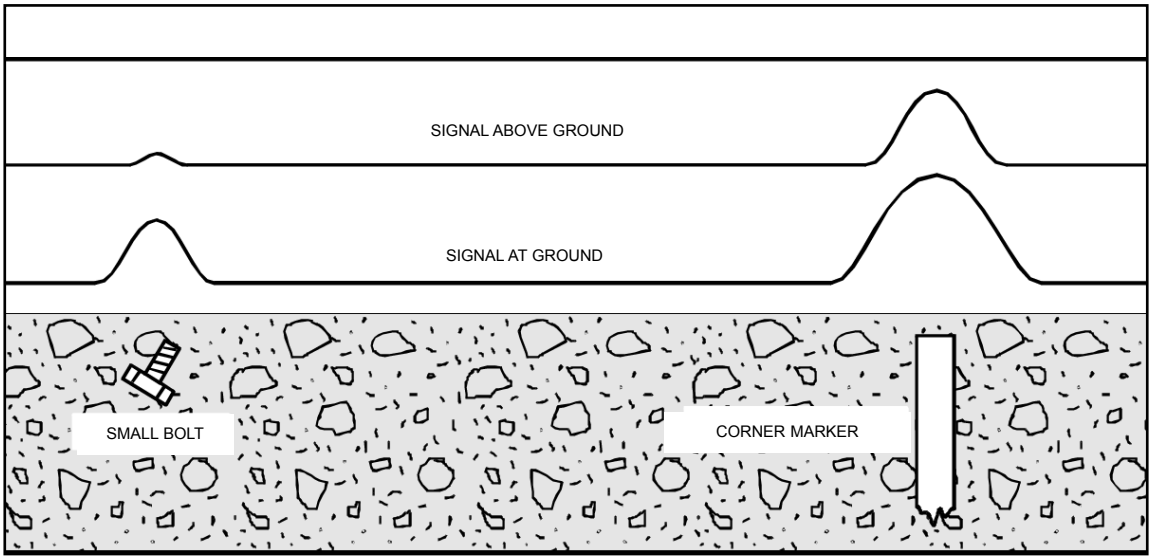


Figure 6. Raising the Locator Eliminates Unwanted Signals

Strongly Magnetized Markers

A strongly magnetized marker at or near the surface may provide location information that is misleading.

The heavy line in Figure 7 represents the variations in tone frequencies when the locator is moved over the marker. When moving the instrument from **A** to **B**, the frequency of the tone increases and then suddenly decreases at **B**. From just beyond **B** the frequency of the tone increases sharply, becomes very high directly over the marker and decrease just before reaching **C**. From **C** to **D** the pattern is the reverse of that from **A** to **B**. It is obvious that the locator must enter the **B-C** region. Otherwise the marker might be assumed to be between **A** and **B**, or **C** and **D**.

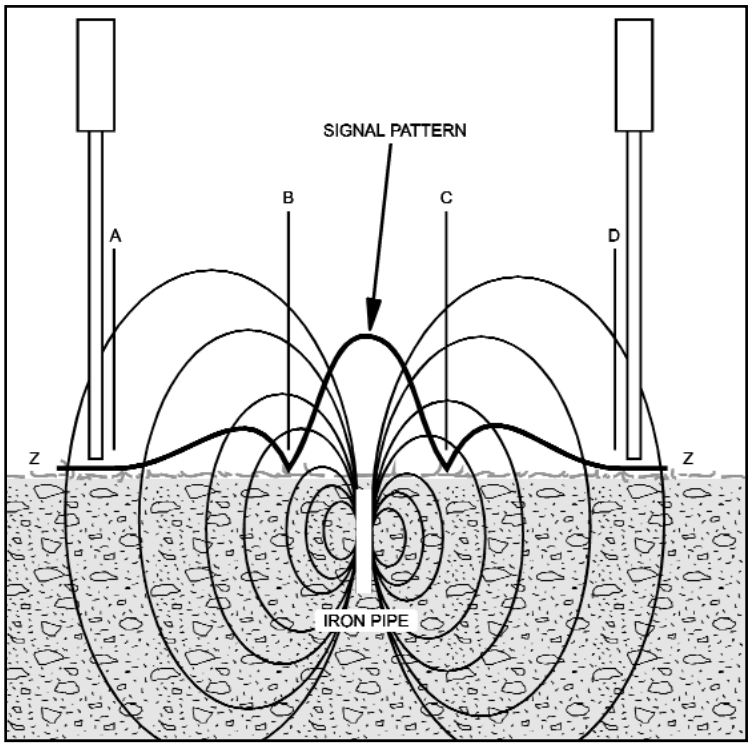


Figure 7. Signal Pattern From a Strongly Magnetized Marker

This phenomenon is explained by the fact that the locator is sensitive to the magnetic field components parallel to its long axis. At points **B** and **C** the field is perpendicular to the locator so no high frequency is produced at these points.

Locating Manholes, Septic Tanks and Well Casings

The magnetic field is strongest at the edge of a shallow manhole cover. You can easily trace the edges of covers near the surface. Locating depth ranges up to 10 feet.

The great length of a well casing provides a strong field at the surface that makes it easy to locate casings buried up to 18 feet deep. The GA-52Cx can be used to precisely locate the metal handles or reinforcing bars on septic tank covers at depths of up to 4 feet.

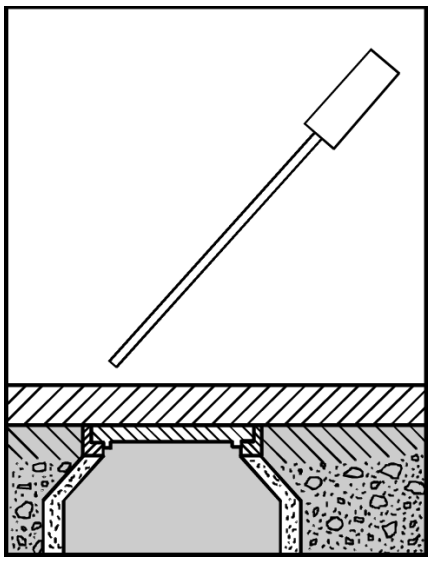


Figure 8. Locating Manhole Covers

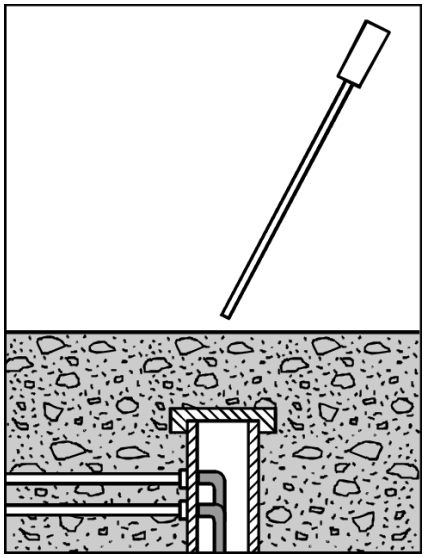


Figure 9. Locating Water Well Casings

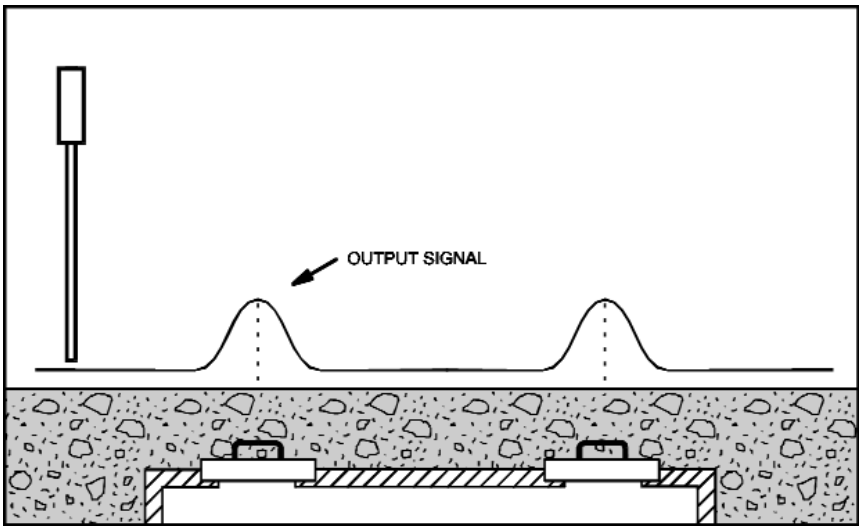


Figure 10. Signal Pattern Provided by Septic Tank Covers

Locating Objects under Snow or Water and Tracing Barbed Wire

The locator can be used in flooded areas, just keep the electronic unit out of the water.

Snow poses no problem. Thrust the locator into the snow as deep as necessary to locate the target.

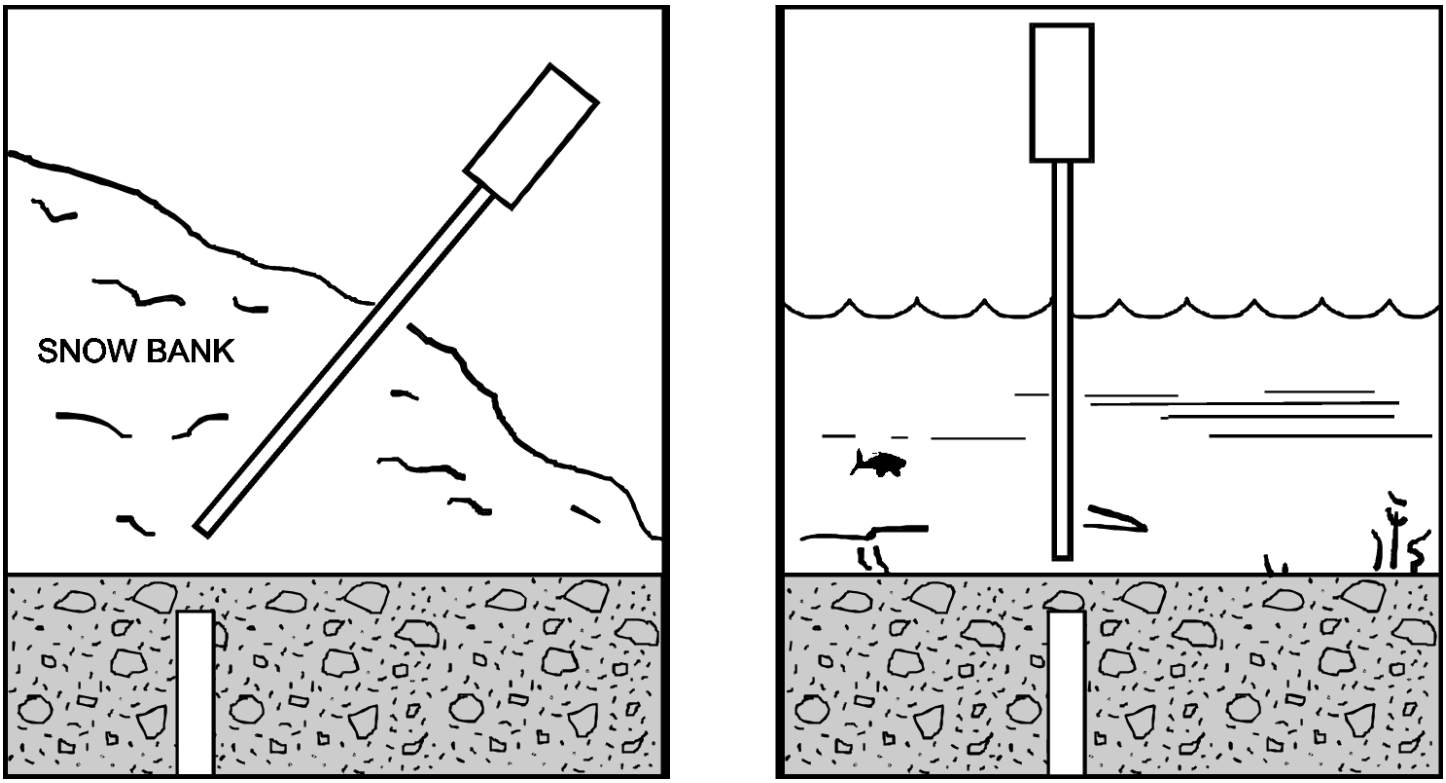


Figure 11. Locating Objects Under Snow or Water

You can often trace barbed wire (from old fence lines) buried just beneath the surface. Even if the wire is only a trail of rust it can still be detected near the surface. Tip the locator a little lower than usual, but not parallel with the ground.

First, examine trees for bench marks and bits of embedded barbed wire. Then hold the locator parallel with the direction of the wire.

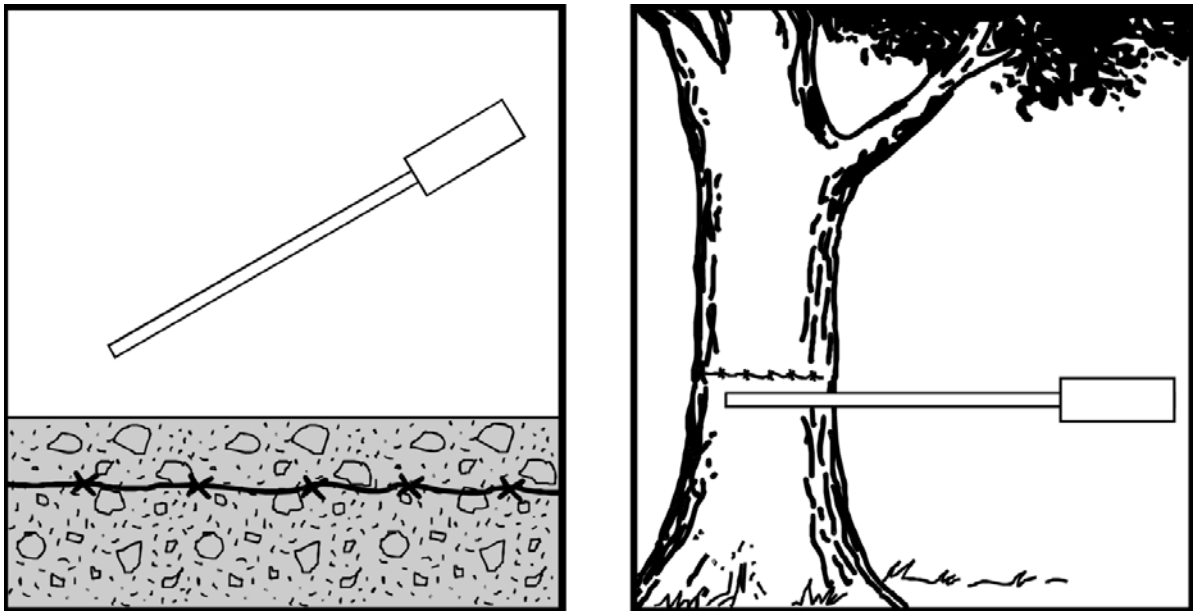


Figure 12. Tracing Barbed Wire from Old Fence Lines

Searching Areas Along a Chain Link Fence

Searching in the vicinity of a chain link fence requires a reduced sensitivity setting and also some control over the orientation of the locator. As illustrated in Figure 13, position the locator horizontally, with its long axis perpendicular to the fence. This ensures that the upper sensor is kept away from the fence.

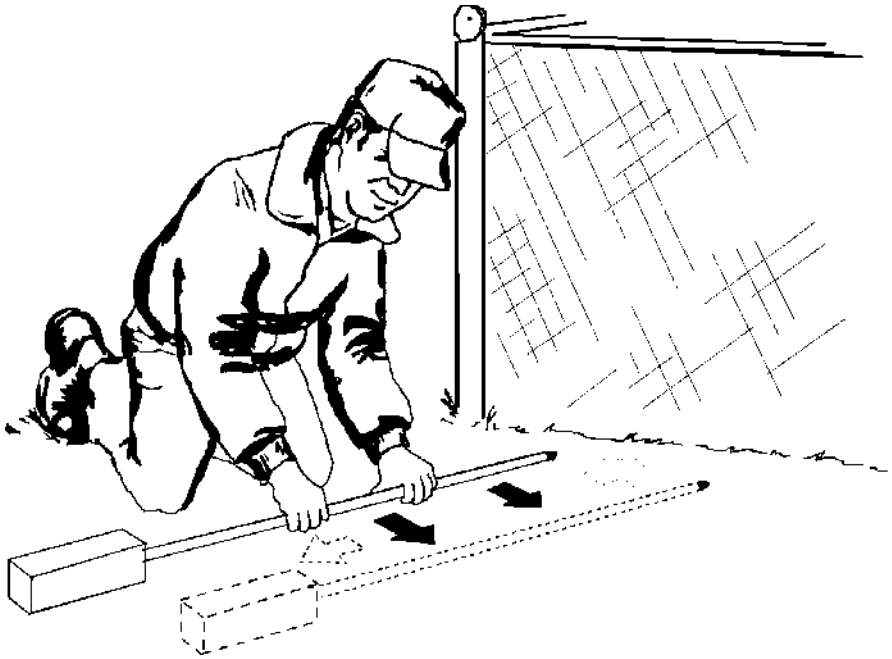


Figure 13. Searching in the Vicinity of a Chain Link Fence

Perform the search by slowly moving the locator forward along the fence while also moving it in to the right and to the left. This technique allows you to search an area several feet wide as you move forward. **Listen for an abrupt drop in the signal, (as shown by the null in Figure 14.) that will occur when the lower sensor, located 1-5/8 inches from the end of the locator, is directly over the stake.** Any variation in the position of the locator will produce an abrupt rise in the frequency of the signal.

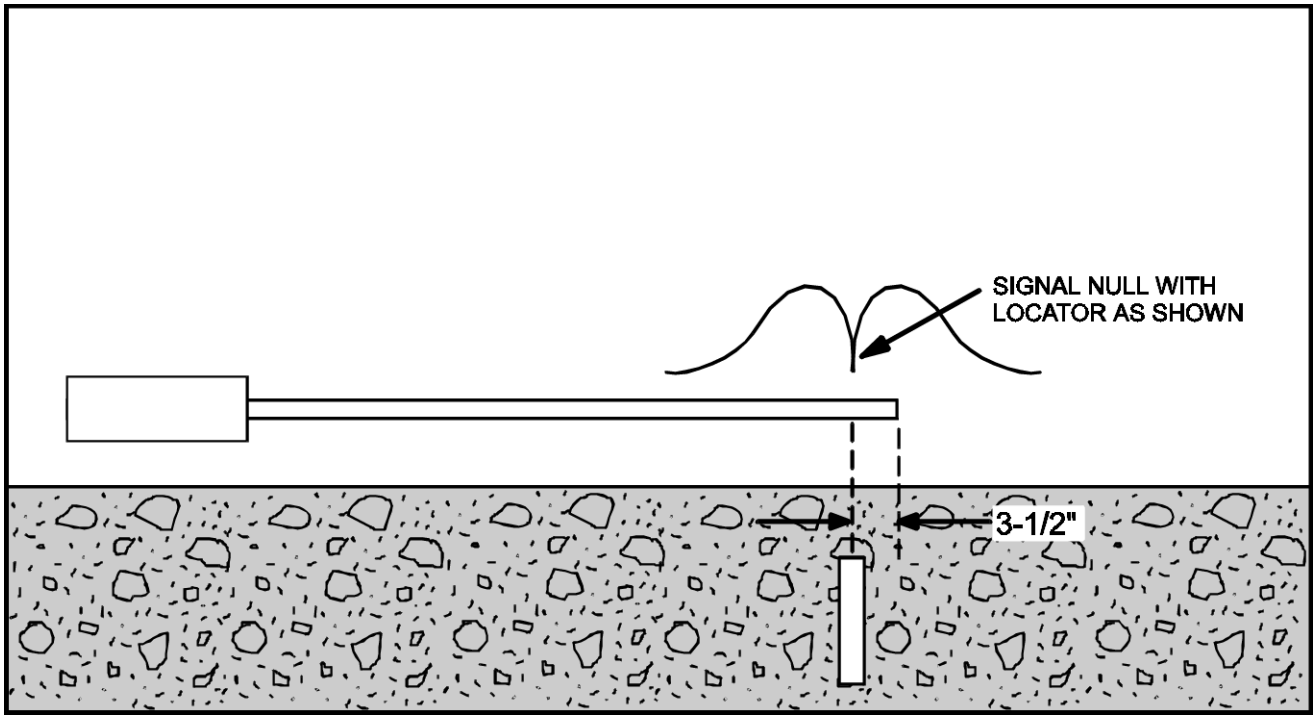


Figure 14. Placement of Locator While Searching Along a Chain Link Fence

Locating Valve Boxes

Both the valve and its casing, when iron, provide strong magnetic fields that make them easy to locate. Plastic enclosures containing magnets are easily located at depths of 10 feet or more.

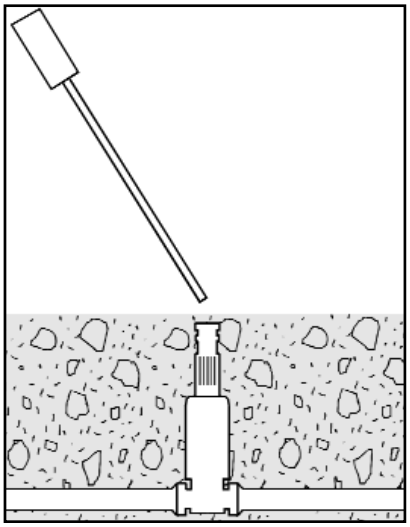


Figure 15. Locating Valve Boxes and Casings

Locating Cast-Iron Pipes

As illustrated in Figure 16, cast-iron pipes produce the strongest magnetic signals at their joints.

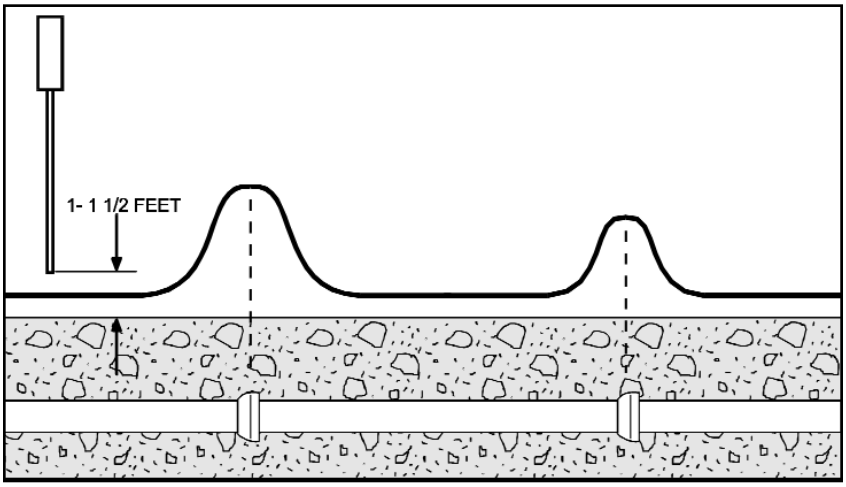


Figure 16. Signal Patterns Provided by Cast-Iron Pipes

The initial search should be performed as follows:

1. Adjust the sensitivity level for maximum.
2. Hold the locator vertically approximately 1 to 1-1/2 feet above the surface.
3. Walk along without turning or tilting the locator.
4. Mark the locations where the maximum signal levels occur.
5. Return to an area of maximum signal strength and hold the locator several inches above the surface. The sensitivity will probably have to be reduced during this second pass. Four-inch pipes can be located at depths of up to 10 feet.

Locating Steel Drums

As shown in Figure 17, the GA-52C*x*'s signal pattern will vary depending on the vertical or horizontal orientation of the drum and also how deep it is buried. A fifty-five gallon drum can be located at depths of up to 10 feet.

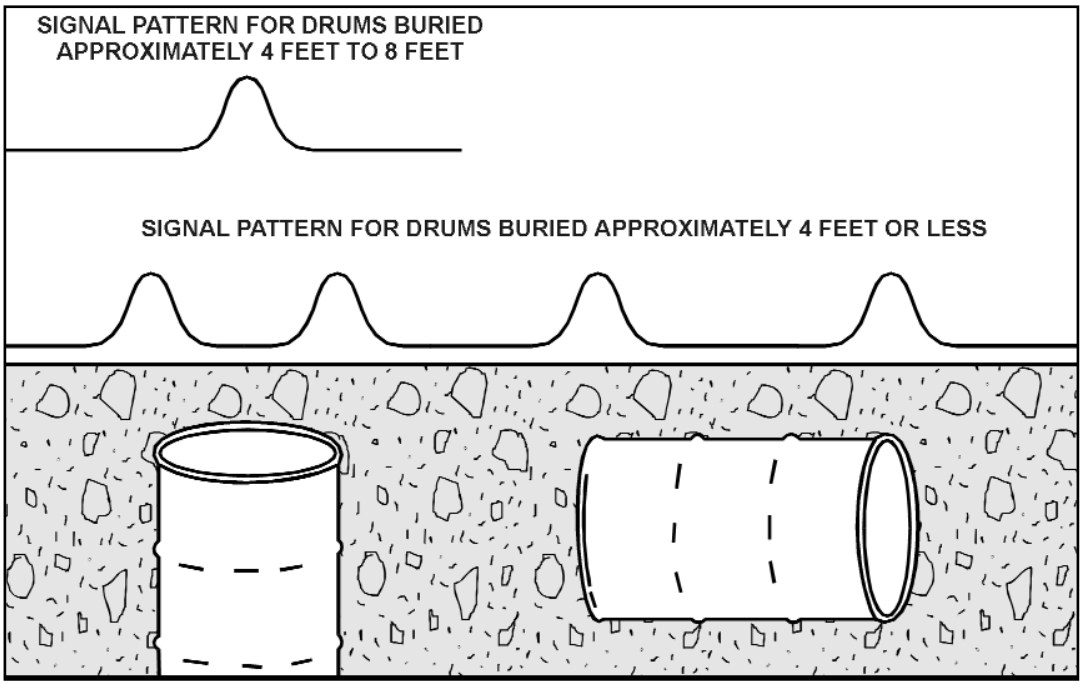


Figure 17. Signal Patterns Provided by Steel Drums

Additional Applications

1. The military and many local and state police departments use the GA-52C*x* to detect buried ordnance and discarded weapons.

2. People drilling in an area where hazardous materials might be encountered use the GA-52C*x* to search the area prior to drilling. Other Schonstedt magnetometers are available that can be lowered down the hole for periodic checks as drilling progresses.

Other Notes

1. A burbling sound indicates the presence of an energized power line.

2. The instrument will not detect non-magnetic materials such as gold, silver, copper, brass and aluminum.

Maintenance

The GA-52C*x* is designed and built to give trouble-free operation. Normally, maintenance is limited to the occasional replacement of batteries. In the event that a malfunction does occur, refer to the trouble-shooting guide on page 11. It lists a few problems that can generally be corrected in the field so that you will be able to continue using the locator without interruption.

Replacement of Batteries

The GA-52C*x* is powered by two alkaline 9-Volt batteries. Alkaline or lithium batteries may be used, however lithium batteries are recommended for their exceptional performance. The battery manufacturers advertise a 10 year shelf life, two to four times the operational life of an alkaline battery, as well as being environmentally safe. If battery leakage does occur, lithium batteries do not cause severe damage to the unit as would alkaline batteries.

The batteries are carried in the battery holder as illustrated in Figure 18. Access to the batteries is obtained by removing the two knurled nuts and sliding off the cover. ***Always replace both batteries.***

NOTE

When replacing the batteries hold the instrument by the metal chassis to avoid any contact with the printed circuit board and its components.

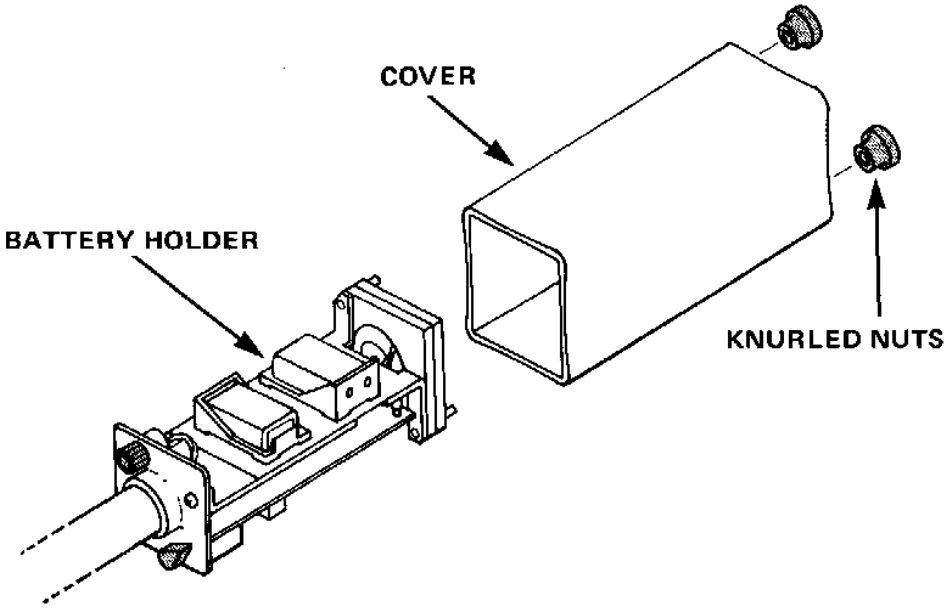


Figure 18. Exploded View of the Electronics Unit Cover

Troubleshooting Guide

Symptom	Possible Cause	How to Check	How to Fix
No response	Dead batteries	Replace	——
	Batteries not making contact	Check for contact corrosion	Clean contacts
	Battery leakage	Do not remove batteries*	Return unit to factory
Intermittent	Batteries not making good contact	Check for corrosion	Clean contacts
Uncontrollable screaming	Weak batteries	Replace	——

*Most battery manufactures' warranties cover the cost of repair or replacement of any device damaged by their batteries. Removing batteries that leak will void their warranty.

SERVICE INFORMATION

If your locator needs service, please return it to the factory (in its case) along with the following information: Name, Address, Telephone and Fax Numbers, Where Purchased, Date of Purchase, and Description of Problem(s). A tele-faxed estimate will be provided prior to service work being done. See shipping information on page 13.

SPECIFICATIONS

(Specifications subject to change without notice)

Input Power: . . . . . Supplied by two alkaline 9-V batteries

Battery Life:. . . . . 40 Hours (intermittent usage)

Output:. . . . . Approximately 40 Hz idle tone in speaker. Tone frequency increases (or decreases) with gradient-field intensity.

Weight: . . . . . Approximately 2.5 lbs. (1.13 kg)

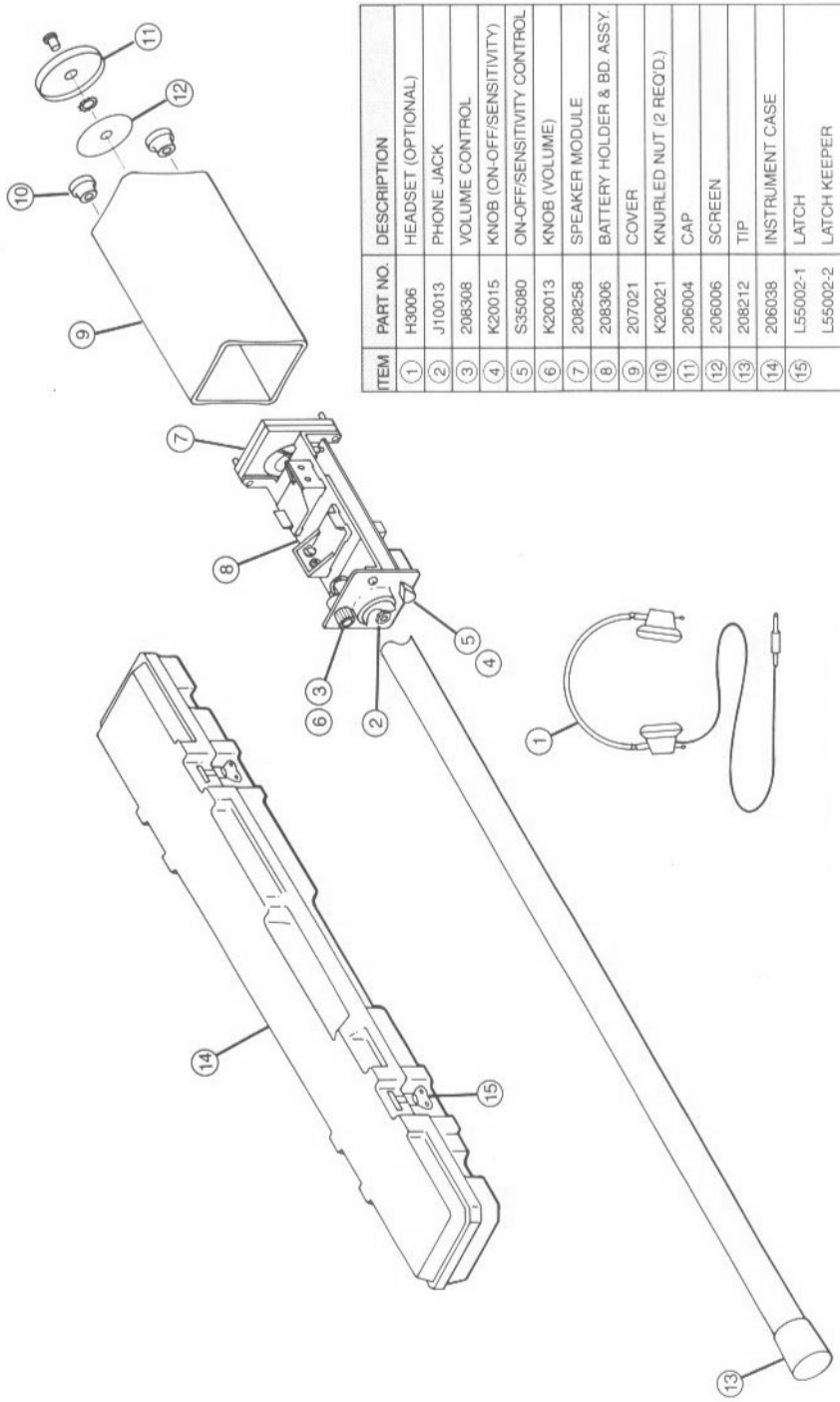
Operating Temperature:. . . . . -13° to 140°F (-25° to 60°C)

Overall Length: . . . . . 42-5/16 in. (107.4 cm)

Waterproof Length: . . . . . 34-1/2 in. (87.6 cm)

Nominal Sensor Spacing: . . . . . 20 in. (50.8 cm)

Construction:. . . . . Rugged, modular all solid state



ITEM	PART NO.	DESCRIPTION
1	H3006	HEADSET (OPTIONAL)
2	J10013	PHONE JACK
3	208308	VOLUME CONTROL
4	K20015	KNOB (ON-OFF/SENSITIVITY)
5	S35080	ON-OFF/SENSITIVITY CONTROL
6	K20013	KNOB (VOLUME)
7	208258	SPEAKER MODULE
8	208306	BATTERY HOLDER & BD. ASSY.
9	207021	COVER
10	K20021	KNURLED NUT (2 REQ'D.)
11	206004	CAP
12	206006	SCREEN
13	208212	TIP
14	206038	INSTRUMENT CASE
15	L55002-1	LATCH
	L55002-2	LATCH KEEPER

LIMITED WARRANTY

The Schonstedt Instrument Company (Schonstedt) warrants each product of its manufacture to be free from defects in material and workmanship subject to the following terms and conditions. The warranty is effective for 7 years (with the return of the Customer Registration Card) after the shipment by Schonstedt to the original purchaser.

Schonstedt's obligation under the warranty is limited to servicing or adjusting any product returned to the factory for this purpose and to replacing any defective part thereof. Such product must be returned by the original purchaser, transportation charges prepaid, with proof in writing, to our satisfaction, of the defect. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. Prior to repair, in this instance, a cost estimate will be submitted. Service or shipping information will be furnished upon notification of the difficulty encountered. Model and serial numbers must be supplied by user. Batteries are specifically excluded under the warranty.

Schonstedt shall not be liable for any injury to persons or property or for any other special or consequential damages sustained or expenses incurred by reason of the use of any Schonstedt product.

FOR SERVICE OR REPAIR

Please ship locator (in its case) to:

Schonstedt Instrument Company
100 Edmond Road
Kearneysville, WV 25430

PATENTS

Manufactured under one or more of the following Patents: United States: 4,163,877; 4,258,320; 4,803,773; 4,839,624; 5,097,211; 5,136,245; 5,138,761; 5,239,290. Other United States and foreign patents pending.

Attachment B
Laboratory SOPs

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Due to their proprietary and confidential nature, analytical laboratory SOPs are removed from this document and not available to the general public.

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Attachment C
Final Responses to EPA and PREQB Comments

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Final Responses to EPA Review of the

Draft Expanded Site Inspection Sampling and Analysis Plan, UXO 15 Former Vieques Naval Training Range, Vieques, Puerto Rico October 2010

General Comments

1. The worksheets do not consistently describe the potential subsurface soil sampling that is proposed as part of the digital geophysical mapping (DGM) activities in PI 9, PI 13, and the two magnetic anomalies. The Executive Summary and Worksheet #10 indicate that subsurface soil samples will be collected from under locations where munitions and explosives of concern (MEC) are found and excavated. However, Worksheet #11, Project Quality Objectives/Systematic Planning Process, and Worksheet #14, Summary of Project Tasks, do not mention the subsurface soil sampling in these areas. Revise the Draft Expanded Site Inspection Sampling and Analysis Plan, UXO 15 (ESI SAP) to consistently describe the planned subsurface sampling in all worksheets.

   Navy Response:

   Text has been added to Worksheet #11 as follows:

   A fourth bullet has been added to Question #5 that states:

   "If subsurface MEC is identified during the DGM, they will be excavated and soil samples will be collected beneath them in a manner consistent with the approach for any surficial MEC identified."

   Another bullet has been added at the end of Worksheet #11 that states:

   "- Soil samples will be collected beneath any MEC items identified and excavated during the DGM investigation at PI 9, PI 13 and the EADAs. The soil samples will be collected from the 2-inch interval beneath the items following their removal." The above text has also been added to Worksheet 14, Excavation of Subsurface Anomalies, at the end of the second paragraph.

2. The unexploded ordinance (UXO) avoidance, geophysical mapping, and waste disposal subcontractors have not been specified. Revise the ESI SAP to provide this information. Alternatively, if the subcontractors for these positions have not been obtained, indicate that this information will be submitted as a SAP addendum.

   Navy Response:

   Worksheets #3, #4, #5, #6, and #7 will be updated to show that the UXO avoidance work and geophysical mapping will be done by CH2M HILL personnel. It also will be updated to list USA Environmental as a contractor that will handle the task of removing munitions debris from the water at the PI 9 former pier site and any other MEC or munitions debris found. The IDW disposal subcontractor has not been chosen yet. If they are chosen prior to the final version of the SAP they will be added; however, if they

are selected after the final version is produced, that information will be included in the ESI report. The box labeled as Test Pitting Subcontractor – TBD has been changed to "Debris Removal/Excavation Subcontractor – TBD."

3. The rationale for the number and type of soil samples proposed in this ESI SAP has not been provided. It is unclear why one sample per debris pile is sufficient to meet project goals, and what type of sample is proposed (e.g., grab, composite, or multi-increment). Revise the ESI SAP to include the rationale for number and type of soil samples.

   Navy Response:

   Worksheet #10, Environmental Questions to be Answered by the ESI Sampling, Question 1 describes the number of samples necessary to achieve the objective of the question. The word "discrete" has been added to the first sentence of the response to this question as follows: "…will be removed and one discrete soil/sediment sample will be collected beneath . . . ." and in the last sentence as follows: "…will be removed and an additional discrete soil/sediment sample will be collected beneath each." The number and type of soil samples was concurred upon by the Vieques Technical Subcommittee during the July 2010 Technical Subcommittee Meeting (see Worksheet #9 and the seed file that was discussed during the meeting). In addition, the following rationale has been added: "One sample per debris pile was determined to be sufficient based on the relatively small size of the piles (i.e., less than approximately 10ft x 10ft)."

4. The ESI SAP does not provide the laboratory specific quality control (QC) acceptance limits for many analytes. Instead, the ESI SAP references the Department of Defense (DOD) Quality Systems Manual (QSM) limits. While it may be acceptable to use the DOD QSM acceptance limits, the ESI SAP should provide laboratory specific values to ensure the DOD QSM values can be met. Revise the ESI SAP to provide this information.

   Navy Response:

   The laboratory will follow the DoD QSM v. 4.1 QC acceptance limits and are required to take action if they fall outside the limits.

5. The ESI SAP does not discuss manual integrations for chromatographic analyses. Revise the ESI SAP to ensure that if manual integration is required, the supporting information (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:

   This information is automatically provided by the laboratory when required. A row for "Chromatograms Before and After Manual Integration" maintained "Hardcopy in the full data package. Archived at project closeout." has been added to Worksheet #29. A row for "Brief Explanation for Manual Integration (when required)" maintained "Included with the case narrative." has been added to Worksheet #29. The data validator already considers manual integration during data validation. "The data

validator considers manual integration" has been appended to Footnote 1 on Worksheet #36.

6. The ESI SAP indicates that metal analytes will be determined by EPA Method 6010B and 6020; however, there are newer methods available for these analyses. Revise the ESI SAP to indicate that Methods 6010C and 6020A will be used in place of Methods 6010B and 6020. Alternatively, if Method 6010B and/or 6020 will be used, ensure that a post digest spike (PDS) is analyzed when the matrix spike/matrix spike duplicate (MS/MSD) recoveries exceed acceptance criteria.

   Navy Response:

   Just because newer methods are available, does not mean they automatically should be utilized. Methods may change between the time a draft SAP is developed and the final SAP is prepared; it is not necessary to automatically change to the newer method if the proposed method is still appropriate. Having to automatically change methods after the laboratory procurement and draft SAP have been prepared places undue burden on the project for little or no added value. SW-846 6010B and 6020 are appropriate given the data needs for this project. Post-digestion spike is already required, when necessary, as evidenced by Worksheets #28-1 and #28-4. The PDS procedure has been updated to require a PDS when there is matrix spike failure. This requirement will be conveyed to the laboratory and included in Worksheet #28-1 and #28-4.

7. The ESI SAP discusses EPA Method 8330 for analysis of explosives; however, Method 8330B is more appropriate. Revise the ESI SAP to indicate that Method 8330B will be used for explosives analyses.

   Navy Response:

   Based on the March 3, 2011 conference call between EPA and the Navy, it was concurred that certain aspects of Method 8330B will be implemented for the UXO-15 ESI. Specifically, for each explosives sample:

   a. The sample fraction will be collected in a separate jar (from the metals fraction)
   b. The sample will be dried per Method 8330B Section 11.1.4.1
   c. The sample will be ground using mortar and pestle to a 10 mesh grain size
   d. The laboratory will subsample 30 increments to form an aliquot for extraction
   e. The analysis will include the 8330B list of analytes

8. The ESI SAP does not contain data validation checklists. Instead, the ESI SAP references multiple guidance documents when discussing how data will be qualified. For each analytical method, either an applicable EPA data validation standard operating procedure (SOP) should be referenced, or a data validation checklist must be provided. Revise the ESI SAP to provide the data validation checklists or reference the applicable EPA Region 2 procedure.

   Navy Response:

   Data validation is performed as described in Worksheet #36. Data validation checklists are only required when an analytical method is performed for which there is an EPA

Region II SOP for data validation. On Worksheet #36 for EXPLO, "Note that this document is specific to SW-846 8330" has been corrected to "Note that this document is specific to SW-846 8330A" to fix a typo. For perchlorate, the data validator will not provide an in-house checklist. On Worksheet #36, the last sentence under "Perchlorate" has been revised to read: "Data qualifiers will be those typical to EPA Region II."

Specific Comments

1. **Acronyms and Abbreviations, page VII:** This table does not include all of the acronyms used in the ESI SAP. For example, the acronyms NOSSA, TRVs, PQO, EADA, and SSLs are not defined. Revise the ESI SAP to include all acronyms and abbreviations used in the ESI SAP.

   Navy Response:

   The Acronyms and Abbreviations page has been edited to include the above mentioned items and other items identified that were not included in the draft version.

2. **Executive Summary, page XII:** In the third paragraph it is noted that if any subsurface anomaly is identified, it will be excavated and a subsurface soil sample will be collected below it. The discussion should also indicate the constituents of interest (explosives, perchlorate, metals) which will be included in the analysis.

   Navy Response:

   The last sentence of the aforementioned paragraph has been revised to read: ". . . ., then a subsurface soil sample will be collected below it and analyzed for explosives, perchlorate, and metals."

3. **SAP Worksheet #1, Title and Approval Page, page 1:** It appears that space for the signatures of the Investigative Organization's (CH2M Hill's) Program Manager and Quality Assurance (QA) Officer has been omitted. Revise the ESI SAP to provide space for these personnel to sign.

   Navy Response:

   The signature page is correct as written, except that the NAVFAC QA Officer signature will be removed from the draft final and final versions.

4. **SAP Worksheet #5, Project Organizational Chart, page 11:**

   a. The organizational chart does not include the subcontractors for the excavation activities or investigation-derived waste (IDW) disposal at the site. Revise the chart to include the excavation and IDW disposal subcontractors.

      Navy Response:

      Both the excavation and the IDW disposal subcontractor have not been chosen yet. If they are chosen prior to the final version of the SAP they will be added; however, if they are selected after the final version is produced, that information will be

included in the ESI report. The box labeled as Test Pitting Subcontractor – TBD has been changed to "Debris Removal/Excavation Subcontractor – TBD."

b. A test pitting subcontractor has been included in the organizational chart, but Worksheet #14 indicates that test pitting will no longer be conducted. Revise the chart to remove the test pitting subcontractor.

Navy Response:

See response to comment 4a above.

5. **SAP Worksheet #6, Communication Pathways, pages 13 to 14:** It is unclear from this table if EPA and other regulatory agencies will be notified when significant corrective actions or deviations from the SAP occur. Revise the ESI SAP to indicate that EPA and other regulatory agencies will receive notification of significant corrective actions and deviations from the SAP. Also, revise the ESI SAP to include the form of communication and timeframe for these notifications.

Navy Response:

As has been done in all recent reports, deviations or corrective actions from SAPs are described in the associated reports. If a particular deviation will prevent the investigation from meeting the objective(s) stated in the SAP, the regulatory agencies will be notified as soon as an alternative approach has been considered between the Navy and CH2M HILL. This information has been added to Worksheet #32.

6. **SAP Worksheet #7, Personnel Responsibilities Table, pages 15 to 16:** This table appears to be missing the project responsibilities for the Project Managers of both analytical laboratories and the project responsibilities for the UXO avoidance, geophysical, and excavation subcontractors. Revise the ESI SAP to provide the project responsibilities for the personnel who will perform the aforementioned activities.

Navy Response:

The five individuals mentioned above have been added to Worksheet #7.

7. **SAP Worksheet # 9, Consensus Decisions, page 21:** The second bullet should clearly indicate that 4 soil samples will be collected underneath debris piles A-D, and a sediment sample will be collected under debris pile E. Please note that discrete samples will be collected SAP worksheet # 14 (page 44).

Navy Response:

Worksheet #9 consists of an excerpt from the meeting, so it is not appropriate to edit that text. However, the first sentence of the answer to the Environmental Question 1 in Worksheet #10 has been revised to read: ". . . beneath each of the five large debris piles identified (the samples beneath debris piles A through D are assumed to be soil and the

sample beneath debris pile E is assumed to be sediment)." This information has also been added to the last bullet of Worksheet #11.

8. **SAP Worksheet # 10, Problem Definition, Conceptual Site Model, Physical Characteristics, page 24:** Please note whether debris pile E is considered part of the tidal swamp.

   Navy Response:

   The following sentence has been added to the end of the third paragraph under "Physical Characteristics" (page 24): "Debris pile E is located on sediment within the intertidal zone of the lagoon."

9. **SAP Worksheet # 10, Problem Definition, Potential Source of a CERCLA Releases and Release Mechanism, first paragraph, page 25:** The first sentence should indicate that the surface soil and sediment samples will only be collected under debris piles; the environmental characterization outlined in this SAP does not involve sampling over the entire site.

   Navy Response:

   The first sentence has been edited to read: "The UXO 15 ESI will include the environmental characterization of soil and sediment beneath debris piles and any subsurface MEC identified."

10. **SAP Worksheet # 11, Project Quality Objectives/Systematic Planning Process Statement, 2. What are the Project Action Limits (PALs)?, second bullet, page 29:** Please include the reference CH2M HILL, 2010C which is the Master ERA Protocol Update 1, August 2010.

    Navy Response:

    The second bullet has been updated to read:

    – "Vieques ecological screening values for soil, which are listed in the Vieques Master Ecological Risk Assessment Protocol (CH2M HILL, 2010a) and associated Master ERA Protocol Update 1 (CH2M HILL, 2010c)."

11. **SAP Worksheet #11, Project Quality Objectives/Systematic Planning Process Statement, 2. What are the Project Action Limits (PALs)?, seventh bullet, page 30:** The discussion of limits of detection (LODs) exceeding project action limits (PALs) states that past experience has shown that SSLs are not reliable predictors of leaching to groundwater because they are overly conservative for the Vieques site. However, it is unclear how this conclusion was derived as information to support this statement has not been provided or referenced. Revise the ESI SAP to provide this information or specifically reference (i.e., document name, date, and section) where it can be found.

    Navy Response:

    The following has been added to the last sentence of the last paragraph under Question 2:

"... leaching to groundwater; they are overly conservative (see multiple site-specific SSL discussions contained in the Site Inspection/Expanded Site Inspection Report [CH2M HILL, 2010d)."

The following reference has been added to the References section:

"CH2M HILL. 2010d. Final Site Inspection/Expanded Site Inspection Report, 7 Consent Order Sites and 16 PI/PAOC Sites, Former Vieques Naval Training Range, Vieques, Puerto Rico. August 2010.

12. **SAP Worksheet #11, Project Quality Objectives/Systematic Planning Process Statement, Further Investigation or Action Determination (Steps 5 and 6 of Figure 1), page 32:** The section describing further investigation or action based on the data collected for this SAP is unclear. The text states that further investigation will be determined by evaluating the data collected from the proposed sampling. Revise this section to clarify that if additional investigation is required, a new SAP or SAP addendum will be prepared.

Navy Response:

The following has been added after the first sentence under the aforementioned heading:

"If additional investigation is warranted, a SAP addendum or a new SAP will be prepared, as appropriate."

13. **SAP Worksheet # 11, Project Quality Objectives/Systematic Planning Process Statement, Further Investigation or Action Determination (Steps 5 and 6 of Figure 1), page 33:** As previously discussed, please clearly indicate that four soil samples and one sediment sample will be collected. The second sentence discusses additional sampling should debris piles of "comparable" size be found. Please indicate what the comparable size is, and what size would constitute the need for an additional sample.

Navy Response:

Please see the response to Specific Comment 7. In addition, the second sentence on page 33 has been revised to read:

"If other piles of comparable size (approximately 10 ft x 10 ft) are found during the investigation, an additional soil sample will be collected beneath each. If larger debris piles are found, multiple samples will be collected in comparable increments (i.e., one additional sample per approximate additional 10 ft x 10 ft area of debris."

14. **SAP Worksheet #13, Secondary Data Criteria and Limitations, page 39: The** discussion of Limitations on Data Use should provide a more quantitative description for determining which existing data are appropriate for use. Revise Worksheet #13 to provide this information.

Navy Response:

The data listed in the table are the data that were used to generate the ESI sampling approach and locations, which was concurred upon by the Technical Subcommittee

during the July 2010 Technical Subcommittee meeting. It is unclear from the comment what additional information is necessary.

15. **SAP Worksheet # 14, Summary of Project Tasks, Digital Geop**hysical Mapping, Biological Assessment Prior to Vegetation Clearance, page 41: EPA would appreciate a copy of the completed biological assessment report.

    Navy Response:

    The biological assessment report will be included as an appendix of the ESI report.

16. **SAP Worksheet #14, Summary of Project Tasks, Sample Location Mark-out, page 43:** This worksheet indicates that the sampling locations will be established using a global positioning System (GPS) unit, but does not discuss the accuracy of the GPS. Revise the ESI SAP to discuss the accuracy requirements of the GPS unit and how they will be met when establishing sample locations.

    Navy Response:

    Section titled Sample Location Mark-out, first sentence has been edited to read: "The sampling locations will be established using Real Time Kinematic (RTK) Global Positioning System (GPS) coordinates, accurate to approximately 2 centimeters, depending on ambient conditions such as canopy cover."

17. **SAP Worksheet #14, Summary of Project Tasks, Equipment Decontamination, page 45:** The ESI SAP indicates IDW will be managed in accordance with the Master Protocols. However, the ESI SAP does not reference or provide any specific protocols. Revise the ESI SAP to specifically reference the applicable protocols. Further, indicate specifically where the protocols can be found.

    Navy Response:

    The first sentence of the second paragraph of Section Equipment Decontamination on Page 45 has been edited to read:

    > "IDW will be managed and disposed of in accordance with the Master Waste Management Plan (CH2M HILL 2010a)."

18. **SAP Worksheet #14, Summary of Project Tasks, Data Management, page 45:** The description of data management is insufficiently detailed. Worksheet #14 indicates that data are entered into a database, but it is unclear if the database is compared to the hard copy data to ensure its accuracy and if validation qualifiers will be entered into the database to ensure qualifications are considered when using the database. Revise the ESI SAP to provide the details discussed in Section 2.8 of the *Uniform Federal Policy for Quality Assurance Project Plans Manual*, March 2005 (UFP QAPP Manual).

    Navy Response:

    Comparison of the hardcopy to the electronic deliverable is a routine verification task already described (Verification Input is "Electronic Data Deliverables") in Worksheet #34. The data validator applies validation qualifiers to the electronic deliverable prior to loading into the database. To clarify this, a row for "Validation Changes" has been

inserted above "Audit Reports" on Worksheet #34. The description is "Validation qualifiers are applied to the electronic deliverable prior to loading in the database. A 100% check on data validation changes (between the hardcopy data validation report and electronic deliverable) is performed by the project chemist." This is "Internal." The Data Validator and Project Chemist are responsible for these verification tasks. Further, the laboratory is required to provide the data in the format and structure that the database recognizes, so there is an inherent check when the data are uploaded. In other words, the database would not accept the data if they were not in the correct format.

19. **SAP Worksheet # 15-1 Reference Limits and Evaluation Table, page 47:** Please note that as soil TRVs for aluminum and iron are based on pH levels they are not included in this table. However, soil pH levels should be taken into account when determining whether these inorganics pose risk to ecological receptors.

Navy Response:

The following text has been added to the footnote after the sentence that ends ". . . interpret the other metals results.":

> "Soil TRVs for aluminum and iron are based on pH levels and thus are not included on this table. Soil pH levels are considered when determining whether aluminum and iron pose risk to ecological receptors."

20. **SAP Worksheet #15, Reference Limits and Evaluation Table, pages 47 to 51:**

    a. The table indicates that the project action limit (PAL) is less than the LOD in many cases. Revise the ESI SAP to discuss why a potentially more sensitive method (e.g., Method 6020A) is not proposed.

Navy Response:

In most cases (such as for explosives), a potentially more-sensitive method is not available. In the case of chromium in surface soil and sediment, the PAL is less than the LOD because the PAL assumes that chromium present at the site may be present as hexavalent chromium. Speciation for hexavalent chromium is already being performed. It should also be noted that there are no specific constituents of interest for this project (which is why the general TAL is being analyzed rather than a specific constituent(s)). Rather, there are analyte groups of interest. If the results of the ESI suggest a particular constituent(s) should be further evaluated and that a modified method is warranted, it will be considered at that time. Method modifications are not warranted at this time considering the analytical complications and difficulties (increased interferences, additional dilutions and reanalyses, etc.) that switching to a more-sensitive method creates. LODs exceeding PALs is a common situation in all projects that are evaluating analyte groups, which creates an acceptable level of uncertainty. Historically, analysis of thallium via SW-846 6020 has automatically been proposed at Vieques due to concerns over interference issues associated with older methods. These concerns are no longer applicable because the current method does not suffer from those historical interferences. Going forward, SW-846 6020 will not automatically be proposed for thallium unless it is required to meet a particular data need. However, arsenic and chromium will be analyzed by

Method 6020 because these two constituents, using Method 6010, have LODs higher than the PALs, which are based on the human health screening levels.

b. The difference between the LOD, limit of quantification (LOQ), and the detection limit (DL) are not established. Revise the ESI SAP to discuss how the LOD, LOQ, and DL are obtained and discuss the differences between them.

Navy Response:

Laboratories report according to DoD QSM v. 4.1. The UFP-SAP is not the appropriate document for discussion of the definition and use of LOQ/LOD/DL. Recently, CH2M HILL prepared a technical memorandum to discuss LOQ/LOD/DL. The purpose of this memorandum was to help inform those who are not yet familiar with the switch to LOQ/LOD/DL reporting. It has been attached to these responses. A footnote has been added/revised in each applicable Worksheet #15 indicating "LOQ/LOD/DL are as defined in DoD QSM v. 4.1." In addition, the web address for DoD QSM v. 4.1 has been added to the References section. Also, the SAP has been revised to consistently use the LOQ/LOD/DL terminology instead of the QL/MDL.

c. The upper tolerance limits (UTLs), defined as Vieques background inorganics levels in soil, do not appear to be included in Worksheet #15. Worksheet #11 defines these levels as PALs for determining if a release of metals has occurred. Revise the ESI SAP to provide these UTLs.

Navy Response:

Results may be compared to background levels but background levels are not used to determine PQL goals. Therefore, the background values are not included on Worksheet #15.

d. The table does not indicate whether quantitation limits (QLs) and PALs for soil samples are based on wet or dry weight. Revise the table to indicate that QLs and PALs are based on dry weight, and ensure that the laboratory results are reported as dry weight.

Navy Response:

PALs are based on dry weight. Except in rare cases (such as tissue data), QLs and results for solid samples are always reported on a dry-weight basis. Dry-weight basis is the default for reporting unless otherwise specified. Therefore, no revision to the table is warranted. A footnote has been added/revised in each applicable Worksheet #15 indicating the results are presented on a dry weight basis.

21. **SAP Worksheet # 15-2, Reference Limits and Evaluation Table, page 50:** Please note that the soil TRV for nitrobenzene (NB) should be 2,260 µg/kg rather than 2,200 µg/kg (as per the ERA Protocol, Table 18).

Navy Response:

The soil TRV for nitrobenzene on Worksheet #15-2 has been updated from 2,200 µg/kg to 2,260 µg/kg.

22. **SAP Worksheet #17, Sampling Design and Rationale, page 57:** The table identifies 4 soil samples and 1 sediment sample to be collected from UXO 15 and references Figure 17 for the location of these proposed samples. However, Figure 17 does not include sample locations; it includes 4 pink dots showing debris piles, 1 green dot showing a small arms pile, and 2 orange dots showing depressions observed by FWS. An assessment of the number and locations of samples cannot be made from this figure. The figure should be revised to more clearly delineate the debris piles and arms pile, so that the sample locations can be evaluated. EPA agrees that the purpose of the sampling for the ESI is to determine whether a release has occurred, but a total of 4 samples for this area may be insufficient to make that determination.

    Navy Response:

    The number of samples was concurred upon by EPA during the July 2010 scoping session and the March 3, 2011 conference call between EPA and the Navy. The debris piles are so small that they would not show up in a figure of the scale of Figure 17. The dots represent where the debris piles are located.

23. **SAP Worksheet # 18, UXO 15 Sampling Locations and Methods/SOP Requirements Table, page 59:** The sampling interval for the sediment sample should be the same interval as the soil sample for the Debris Piles Samples, 0-6- inches bgs for explosives and metal, rather than 0-2 inches which will be used for the potential MEC samples.

    Navy Response:

    The depths listed in Worksheet 18 are correct as written. The sediment sample listed has a 0-2-inch depth because the debris pile associated with that sample is composed entirely of MEC items. Worksheet 17 has been edited to a Depth of Sample of "6-inch interval below debris" for Surface Soil. Note footnote "b" also clarifies when a 2 inch interval and when a 6 inch interval will be collected.

24. **SAP Worksheet #19, Analytical SOP Requirements Table, page 61:**

    a. The aqueous sample holding time before extraction for EPA Method 8330 is defined as 14 days; however, the sample should be extracted within seven days. Revise the ESI SAP to list the seven day holding time required for aqueous analyses.

       Navy Response:

       The holding time for aqueous (AQ) 8330 on Worksheet 19 has been updated from "14 days / 40 days" to "7 days / 40 days." The holding times for the soil and sediment do not change.

    b. The table does not specify the type of glass container to be used for the collection of soil samples for perchlorate analyses. SOP WS-LC-0012 states that soil samples to be analyzed for perchlorate must be collected in amber glass containers. Revise the ESI

SAP to specify that an amber glass container will be used for samples to be analyzed for perchorate.

Navy Response:

Worksheet #19 has been updated to indicate that SD and SS samples (to be analyzed for perchlorate) shall be collected into an amber glass jar. In addition, a footnote will be added to Worksheet 19 to indicate: "The number and type of sample containers may vary slightly as long as they are acceptable for the analytical procedure(s)."

25. **SAP Worksheet #20, Field Quality Control Sample Summary Table, page 63:**

a. The footnote (4) indicates that the number of equipment blanks is based on the number of sampling days each site will require and that soil sampling will occur over two days. Worksheet #12 indicates that equipment rinsate blanks will be collected for each day of sampling. Revise this worksheet to indicate that a equipment blank will be collected for each day that sampling occurs.

Navy Response:

Worksheet #12 provides the frequency requirement for equipment blank collection. Worksheet #20 provides an estimate, based on an assumption of the number of days of sampling that may be required, of the actual number of equipment blanks that may be collected. Because two days of sampling are anticipated, it was assumed that one equipment blank would be required for soil and one equipment blank would be required for sediment. If more equipment blanks are required, then more equipment blanks will be collected, based on the protocol stated in Worksheet #12. Footnote #4 in Worksheet #20 has been revised to read: "See Worksheet #12 for collection frequency."

b. This table does not include the QC samples for the potential subsurface samples where MEC is identified by DGM. Revise the ESI SAP to include the potential subsurface samples and the appropriate QC samples in this table.

Navy Response:

At this time, only surface soil and sediment samples are anticipated. In the event that subsurface soil samples are required (i.e., subsurface MEC is found), they will be treated, as applicable considering standard practices, similarly to surface soil samples. This information has been added to Worksheet #14.

26. **SAP Worksheet #22, Field Equipment Calibration, Maintenance, Testing, and Inspection Table, page 67:** This worksheet does not provide a table listing the field equipment required for the proposed sampling activities. The sampling activities described in the ESI SAP appear to require metal detectors and GPS units for identifying sample locations. Revise the ESI SAP to include all field equipment that will be used for the planned sampling activities at UXO 15 as discussed in Section 3.1.2.4 of the UFP QAPP Manual.

Navy Response:

Worksheet #22 has been edited to include the geophysical equipment that will be used at the UXO 15 site.

27. **SAP Worksheet #25, Analytical Instrument Equipment Calibration, Maintenance, Testing, and Inspection Table, page 73:** It appears that two SOPs cited in this table are incorrect. SOP CA-708 cited for analysis of pH and the SOP CA-773 cited for hexavalent chromium do not appear to be included in the attached SOPs. Revise this ESI SAP worksheet to cite the correct analytical SOPs.

    Navy Response:

    Worksheet #25 has been updated to remove references to CA-708 because aqueous pH samples are not required. Worksheet #25 has been updated to change "CA-773" to "CA-772" to correct a typo.

28. **SAP Worksheet #23, Analytical SOP References, page 69:** The revision dates are missing for several SOPs. Revise the ESI SAP to include the revision dates in the final draft.

    Navy Response:

    The revision date is present for each SOP on Worksheet #23 in the "Title, Revision Date, and/or Number" column. The reference to the February 13, 2009 re-visitation date for perchlorate has been removed. In addition, the column heading has been changed to "Date Last Reviewed if not Revised."

29. **SAP Worksheet #27, Sample Custody Requirements Table, page 77:**

    a. The process for how field duplicate samples will be identified is not provided. Revise the ESI SAP to ensure that QC samples are submitted as blind duplicates.

       Navy Response:

       Field duplicates are blind to the laboratory. After "preservative, and sampler's initials" on Worksheet #27, the following sentence has been added:

       "Standard sample nomenclature for blind field duplicates includes a "P" after the station identifier."

    b. The worksheet includes a discussion of labels for solid volatile organic compounds (VOCs). However, VOCs samples will not be collected. Further, example sample labels have not been included. Revise the ESI SAP to remove the discussion of solid VOC labels and include example sample labels for the proposed sampling.

       Navy Response:

       "The following exceptions apply:" and the VOC portion of the bullet has been removed from the Sample Labeling section of Worksheet #27. It is not necessary to include an example sample label in the SAP. The information that will be included on the sample labels is provided in this worksheet. In addition, labels are shipped by the lab with the sample containers at the time of mobilization.

c. It is unclear if custody seals will be used during shipment of samples. According to the SOP attached for chain of custody procedures (SOP H-4), custody seals will be used to prevent tampering with samples. However, this worksheet does not indicate that custody seals will be used. Additionally, example custody seals have not been provided. Revise the ESI SAP to clarify that custody seals will be used for sample shipment, and include example custody seals.

Navy Response:

Custody seals are used for sample shipment. The use of custody seals is described in SOP H-4. The following sentence has been added to the end of the "Field Custody Procedures Section" of Worksheet #27: "See SOP H-4 for details regarding use of custody seals." Like sample labels, an example custody seal will not be included in the SAP; they are delivered along with the sample containers.

30. **SAP Worksheet #28, Laboratory QC Samples, pages 79-81:** The corrective action for non-compliance matrix spike recoveries states "Examine the project-specific DQOs". However, this is not a laboratory corrective action. Revise Worksheet #28 to correct this discrepancy.

Navy Response:

Pages 79-81 (Worksheet #28-1 for SS and SD SW-846 6010B and 6020) were examined. For strict DoD QSM v. 4.1 compliance, corrective action for MS/MSD exceedances begins with "examine the project-specific DQOs." The corrective action procedure is included after this statement.

31. **SAP Worksheet #28, Laboratory QC Samples, pages 85 and 95:** This worksheet does not include surrogates for explosives. Revise the ESI SAP to discuss surrogates for explosives analyses.

Navy Response:

Requirements for surrogate spikes were inadvertently omitted from Worksheets #28-2 and #28-5 for SW-846 8330. They have been added per DoD QSM v. 4.1 Table F-2.

32. **SAP Worksheet #29, Project Documents and Records Table, page 99:**

a. Extraneous documents appear to be mentioned in this worksheet. Worksheet #22 indicates that no field equipment requiring calibration will be used, but several instruments are listed in this Worksheet. Revise the ESI SAP to correct this discrepancy.

Navy Response:

Worksheet #29 has been edited to include only items being used for this investigation.

b. The information presented in this table is insufficiently detailed. For example, it is unclear how long project documents will be maintained or archived before disposal.

Further, the documents listed do not include project report deliverables, laboratory data package deliverables, or what specifically is included in the laboratory data packages. Revise the ESI SAP to indicate the length of time that projects documents will be maintained or archived before disposal, include all applicable project documents, and to present a detailed list of what will be included in the laboratory data packages.

Navy Response:

The aforementioned information has been added to Worksheet #29.

33. **SAP Worksheet #37, Usability Assessment, pages 119 to 120:**

    a. The discussion of the Usability Assessment is insufficiently detailed. For example, this worksheet does not discuss how the data quality indicators (DQIs) (e.g., precision, accuracy, representativeness, completeness, comparability, and sensitivity) will be calculated and/or assessed. Revise the ESI SAP to include a detailed discussion of the DQIs and include the calculation of each DQI.

    Navy Response:

    Worksheets #12 and #28 include requirements for DQIs. Exceedances related to these DQIs will be documented and evaluated by the data validator. If necessary, data will be qualified. The impact of qualification on data use will be discussed in the data quality review. Worksheet #37 includes the following statement: "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." The formulas for calculating precision, accuracy, and completeness have been added to Worksheet #37.

    b. The contents of the data quality evaluation (DQE) report have not been specified. Please revise this section to indicate that the information discussed in Worksheet #37 will be included in the DQE.

    Navy Response:

    Please see the response to Specific Comment 33a.

34. **Figure 3, Aerial and Hand Held Magnetometer Survey Results:** The areas which will undergo test pitting should be clearly indicated.

    Navy Response:

    Test pitting will not be done in this investigation. As noted in Worksheet #14 (page 43), test pitting will not be performed, but excavation of any anomaly identified by DGM within PI 9, PI 13, and the EADA will be performed. Since the excavation locations will be based on the results of the DGM, there are no pre-determined locations to show on a figure.

35. **Figure 17, Proposed Sample Locations:** The figure key should identify the red dots as soil samples and the green dot as a sediment sample. Please discuss the significance of the depression areas identified by orange dots.

Navy Response:

Figures 4 and 17 legend dots have been edited as follows:

Red dot – "Debris Pile and Proposed Soil Sample Location"
Green dot – "Small Arms Pile and Proposed Sediment Sample Location"
Orange dot has been deleted because the depressions observed by FWS are not relevant to this investigation. They were visited and observed to be natural depressions. Therefore, they have been removed from Figure 15.

Final Responses to PREQB Technical Review

Draft Expanded Site Inspection Sampling and Analysis Plan, UXO 15
Former Vieques Naval Training Range, Vieques, Puerto Rico
Dated October 2010

General Comments

1. PREQB recommends that all solid samples being analyzed for hexavalent chromium also be analyzed for pH and ORP. These two analyses (pH and ORP) are very important in determining the reducing nature of the sample and help to interpret the hexavalent chromium data especially when matrix spike recoveries are low. These data are typically plotted on the graph provided at the back of the associated preparation method (SW-846 3060A) to determine whether the sample is reducing in nature. Please revise the SAP and associated worksheets to include the ORP analysis of each soil/sediment sample.

   Navy Response:

   ORP and pH analysis will be included for the soil and sediment samples.

2. It was noted during review of the SAP that the analysis of mercury is not included with the metals analyses of soil/sediment samples. Please clarify the rationale for excluding mercury from analysis.

   Navy Response:

   Mercury is not a contaminant of interest at UXO-15, based on the nature of known or suspected sources there.

Page-Specific Comments

1. SAP Worksheet #3, Distribution List: Several project personnel listed on Worksheets #4 and 5 also need to be included on the SAP distribution list and therefore need to be added to this worksheet.

   Navy Response:

   Worksheet #3 Distribution list has been edited to include individuals listed on Worksheets 4 and 5.

2. SAP Worksheet #5, Project Organizational Chart: Please change the phone extension of PREQB RPM, Wilmarie Rivera. The phone extension is 6129.

   Navy Response:

   The above listed edit has been made.

3. Worksheet #10: Please clarify if whether subsequent investigation indicates that the area was used as a firing point for rocket-related ordnance.

   Navy Response:

   The following has been added at the end of the second paragraph under "Site Background": "However, no evidence of this use has been found or observed at the site."

4. Worksheet #11: Please clarify the following statement: "Even though LODs may be greater than certain PALs, detection limits (DLs) may be closer to or less than PALs. When this occurs, and if a constituent is detected in a sample at or at greater than the PAL, then it is reported, qualified as applicable." Why would a sample be qualified if detected above the PAL? Please clarify.

   Navy Response:

   Laboratories report according to DoD QSM v. 4.1 . Results are qualified (typically J-qualified by the laboratory) when detected at less than the LOQ. If the LOQ > PAL > LOD > DL or if LOQ > LOD > PAL > DL, then a detection at greater than the PAL will be qualified by the laboratory because it is less than the LOQ. Please see the attached memo that discusses LOQ/LOD/DL.

5. SAP Worksheet #15, Reference Limits and Evaluation Tables:

   a. Worksheet #15-1: According to the worksheet, SW-846 method 6020 is being utilized only for thallium. Please clarify why this method is not being used for arsenic, chromium, and cobalt which will then allow the achievement of the EPA Residential Soil Regional Screening Levels (RSLs) for these metals.

      Navy Response:

      Based on the February 28, 2011 conference call between the Navy and EQB, arsenic and chromium will be analyzed by method 6020.

   b. Worksheet #15-1a: According to the worksheet, SW-846 method 6020 is being utilized only for thallium. Please clarify why this method is not being used for antimony, arsenic, cadmium, chromium, cobalt, selenium and silver which will then allow the achievement of the ecological project action levels for these metals.

      Navy Response:

      Based on the February 28, 2011 conference call between the Navy and EQB, arsenic and chromium will be analyzed by method 6020.

   c. Worksheets #15-2 and 15-2a: Please remove the shading for the lower and upper control limits for the LCS recoveries of explosives as these were taken from the DOD QSM v. 4.1.

Navy Response:

The green shading (and defining footnote) on Worksheets #15-2 and #15-2a has been removed.

6. SAP Worksheet #17, Sampling Design and Rationale: Please include methods 6020 and 7196A for metals for each matrix listed on the table in this worksheet.

Navy Response:

Worksheet #17 references to SW-846 6010B have been updated to include 6020 and 7196A.

7. Worksheet #18: Please consider listing the sample depth as 0-2″ for consistency with Worksheet #17. A footnote clarifying that 0-6″ samples will be collected if MEC is not identified in the debris pile may could be added for clarity.

Navy Response:

The depths listed in Worksheet 18 are correct as written. The sediment sample listed has a 0-2-inch depth because the debris pile associated with that sample is composed entirely of MEC items. Worksheet 17 has been edited to a Depth of Sample of "6-inch interval below debris" for Surface Soil. Note footnote "b" also clarifies when a 2 inch interval and when a 6 inch interval will be collected.

8. SAP Worksheet #19, Analytical SOP Requirements Table:

   a. Sediment and Soil:

      i. Please revise the table to show that the preservation requirement for headspace in the jar is applicable to perchlorate only.

Navy Response:

"Headspace in jar" has been clarified to "Headspace in jar (required for perchlorate)" on Worksheet #19.

      ii. Please revise the holding time for hexavalent chromium to include 30 days until digestion and 24 hours from digestion to analysis. This is in accordance with Sections 6.3 and 6.4 of the laboratory's SOP CA-625.

Navy Response:

The holding time for SD and SS Hexavalent chromium has been updated to "30 days / 24 hours."

      iii. Please revise the holding time for pH to "as soon as possible" in accordance with the laboratory's SOP CA-709 and the SW-846 method.

Navy Response:

The holding time for SD and SS pH has been updated to "as soon as possible."

b. Aqueous:
   i. Please include a requirement for headspace in the jar for the perchlorate preservation requirements.

      Navy Response:

      The "headspace in jar" requirement has been moved from hexavalent chromium to perchlorate.

   ii. Please remove the requirement for headspace in the jar from the preservation requirement for metals.

      Navy Response:

      Please refer to response to Comment 8bi, immediately above.

   iii. Please revise the holding time for explosives to 7 days until extraction.

      Navy Response:

      The holding time for aqueous explosives has been changed from "14 days / 40 days" to "7 days / 40 days." The holding times for solid samples does not change.

9. SAP Worksheet #23, Analytical SOP References Table: The Date Last Revised for SOP WS-LC-0012 should be 7/23/10 per the SOP provided in Attachment B. Please revise accordingly.

   Navy Response:

   The reference to the February 13, 2009 re-visitation date for perchlorate has been removed. In addition, the column heading has been changed to "Date Last Reviewed if not Revised."

10. SAP Worksheet #24, Analytical Instrument Calibration Table:

    a. ICP-AES: Please add the PQL standard requirements as described in Section 8.12 of SOP CA-608.

       Navy Response:

       A Low-level calibration check standard has been added per Table F-7 in DoD QSM v. 4.1.

    b. Spectrophotometer:
       i. Please revise the frequency of the initial calibration to daily prior to sample analysis, as per Table 1 of SOP CA-625 (for DOD QSM projects).

          Navy Response:

          The frequency of ICAL has been updated to "Daily, prior to sample analysis" per table F-9 in DoD QSM v. 4.1.

       ii. Please add the ICV as per Table 1 of SOP CA-625.

Navy Response:

An ICV has been added per table F-9 in DoD QSM v. 4.1.

c. LC/MS/MS:
   i. Please include the daily mass calibration requirements as per Section 10.3 of SOP WS-LC-0012.

Navy Response:

Mass calibration requirements have been added per Table F-12 (page F-62) in DoD QSM v. 4.1.

   ii. Please move the Initial and Continuing Calibration Blanks, Interference Check Standard and Internal Standards to Worksheet #28-2.

Navy Response:

The information is correct and is related to calibration procedures. Worksheet #24 is a proper location for these requirements.

11. SAP Worksheet #28, Laboratory QC Samples Table:

a. Worksheets #28-1 and 28-4: 6010B
   i. Laboratory Control Sample: Please revise the Acceptance limits and Measurement Performance Criteria to refer to Worksheet #15-1 instead of 15-8.

Navy Response:

On Worksheet #28-1, LCS and MSD have been updated to refer to Worksheet 15-1. On Worksheet #28-4, LCS and MSD have been updated to refer to Worksheet #15-4.

   ii. Matrix Spike Duplicate: Please revise the Acceptance limits and Measurement Performance Criteria to refer to Worksheet #15-1 instead of 15-8.

Navy Response:

Please refer to response to Comment 11ai, immediately above.

   iii. Add the internal standard requirements as discussed in Section 7.10 of SOP CA-608.

Navy Response:

The use of internal standards for SW-846 6010B is not required by DoD QSM v. 4.1. Please refer to response to Comment 11b, immediately below, for internal standards and SW-846 6020.

b. Worksheets #28-1 and 28-4: 6020: Please add the internal standard requirements as discussed in Section 8.5 and Table 2 of SOP CA-627.

Navy Response:

Requirements for internal standards have been added to SW-846 6020 within Worksheets #28-1 and #28-4 per table F-9 in DoD QSM v. 4.1.

c. Worksheets #28-1 and 28-4: 7196A
   i. The acceptance limits for the sample duplicate are listed as RPD ≤30. However, Section 8.8 of SOP CA-625 states the criteria are RPD ≤20. Please clarify.

      Navy Response:

      For strict DoD QSM compliance, the limit is ≤ 30% RPD for solid samples (Worksheet #28-1) and ≤ 20% for aqueous samples (Worksheet #28-4).

   ii. Please add the requirements for the Calibration Blanks as per Section 8.3 and Table 1 of SOP CA-625.

      Navy Response:

      Requirements for a calibration have been added to Worksheets #28-1 and #28-4 per Table 1 in CA-625.

   iii. Please revise the Measurement Performance Criteria for the Sample Duplicate and the Post-Digestion Matrix Spike to refer to Worksheet #15-1 instead of 15-8.

      Navy Response:

      SW-846 7196A MPCs for LCS and MS on Worksheets #28-1 and #28-4 have been updated to refer to Worksheets #15-1 and #15-4, respectively.

   iv. The Corrective Action for the pre-digestion Matrix Spike does not agree with Table 1 of SOP CA-625 which states to rehomogenize, redigest and reanalyze the sample. Please clarify.

      Navy Response:

      Corrective action for pre-digestion matrix spike on Worksheet #28-1 has been updated to "Correct problem and rehomogenize, redigest, and reanalyze samples. If that fails, evaluate against LCS results. If corrective action fails, apply J-flag to the analyte in all samples in the associated preparatory batch." for strict DoD QSM v. 4.1 adherence.

d. Worksheets #28-2 and 28-5: 8330
   i. Please add the requirements for surrogates.

      Navy Response:

      Requirements for surrogate spikes for SW-846 8330 have been added per DoD QSM v. 4.1 Table F-2.

   ii. Please delete the reference to common contaminants in the method blank acceptance limits and measurement performance criteria since there are no common contaminants in the explosives analysis.

Navy Response:

The sentence "For common laboratory contaminants, no analytes detected > RL" has been removed from Worksheets #28-2 and #28-5 for SW-846 8330. The statement "(see Box D-1 of DoD QSM v 4.1)" is still needed.

iii. Section 8.5 of SOP CA-402 states that one sample per batch must be subsampled in triplicate when analyzing samples compliant with the DOD QSM Version 4.1. Please add this requirement to the worksheet.

Navy Response:

The laboratory triplicate requirement is specific to SW-846 8330B and is not applicable to this project.

e. Worksheets #28-2 and 28-5: 6850

i. The Corrective Action for Isotope Ratios is listed as "NA". Please add the corrective action listed in Section 9.11.3 of SOP WS-LC-0012.

Navy Response:

The corrective action for isotope ratio is correct on Worksheet #28-5 but incorrect on Worksheet #28-2. This information on Worksheet #28-2 has been updated to match Worksheet #28-5.

ii. Please add the requirements for the Synthetic Matrix Check Samples as per Section 9.6.1 of SOP WS-LC-0012.

Navy Response:

The information is present on Worksheet #28-5 (as "interference check sample") but not on Worksheet #28-2. A row has been added to Worksheet #28-2 to match Worksheet #28-5.

iii. Please add the requirements for the internal standards as per Section 9.10 of SOP WS-LC-0012.

Navy Response:

The information is present on Worksheet #28-5 but not on Worksheet #28-2. A row has been added to Worksheet #28-2 to match Worksheet #28-5.

iv. Please add the requirements for the LOD verification standard as per Section 10.12 of SOP WS-LC-0012.

Navy Response:

A row has been added to Worksheet #28-2 and #28-5 for LOD verification per table F-12 in DoD QSM v. 4.1.

v. Please revise the acceptance limits and measurement performance criteria for isotope ratios to the DOD acceptance criteria as per Section 9.11.3 of SOP WS-LC-0012.

Navy Response:

Information for isotope ratio is correct on Worksheet #28-5 but not on Worksheet #28-2. This information on Worksheet #28-2 has been updated to match Worksheet #28-5.

f. Worksheet #28-3: 9045C

i. Please change the frequency for the Laboratory Replicate to one per batch or every 10 samples, as per Section 8.1 of SOP CA-709.

Navy Response:

The frequency for laboratory replicate on Worksheet #28-3 has been updated to "one per batch or every 10 samples" to match CA-709.

ii. Please add the requirements for the Laboratory Control Sample as per Section 8.2 of SOP CA-709.

Navy Response:

A row for LCS has added to Worksheet #28-3. The frequency is "one per batch or every 20 samples." The method / SOP QC acceptance limits is "90-110% recovery." The corrective action is "recalibrate." The person responsible for corrective action is "Analyst, Laboratory Supervisor." The DQI is "Accuracy." The MPC is "90-110% recovery."

12. SAP Worksheet #29, Project Documents and Records Table: Delete row 7 as it is not applicable to this investigation since groundwater sampling will not be performed.

Navy Response:

Worksheet 29 has been revised to list only the documents that will be used during the investigation.

13. SAP Worksheet #31, Planned Project Assessments Table: Stephen Brand was included on the worksheet as the Field Auditor. However, Stephen Brand is also listed as the Field Team Leader on Worksheet #4. Field audits need to be performed by someone independent from the field team.

Navy Response:

The field auditor has been changed to "TBD." The person who will conduct the audit will be determined at the time the project is implemented.

14. Figure 5: Please remove the references to "Section 1 of this SI/ESI Report (October 2009)".

Navy Response:

Footnote 3 has been deleted and all footnotes thereafter have been re-numbered.

Analytical Laboratory Reporting Guidelines per DoD QSM v. 4.1

PREPARED FOR: Vieques Environmental Restoration Technical Subcommittee

PREPARED BY: CH2M HILL on behalf of the Navy

DATE: January 2011

Introduction

On April 22, 2009, the Department of Defense (DoD) released "DoD Quality Systems Manual for Environmental Laboratories" version 4.1, hereafter referred to as "DoD QSM v. 4.1." Although largely based on National Environmental Laboratory Accreditation Conference (NELAC) Chapter 5 Quality Systems (July, 1999), it also includes clarifications and DoD-specific requirements, where more stringent. In addition, it incorporates quality control checks, acceptance limits, and corrective actions that are specific to the various SW-846 methods routinely performed on environmental samples. This technical memo focuses on the analytical laboratory reporting guidelines for detected and non-detect results, the old-style versus new-style, and overall regulatory acceptance of the document.

Old-Style Reporting

Prior to DoD QSM v. 4.1, non-detect results were generally reported as U-Values at the quantitation limit (QL). Results detected between the method detection limit (MDL) and QL were reported and J-qualified to indicate that they were detected at less than the QL. This is also known as "CLP-Style" reporting, which is similar to reporting dictated by EPA CLP methods. EPA CLP methods (for example EPA CLP SOM01.2) refer to a contract-required quantitation limit (CRQL), where non-detect results are reported as U-Values at the CRQL, and detections between MDL and CRQL are reported and J-qualified as "estimated" to indicate that they were detected at less than the CRQL. While "CLP-Style" reporting (U-values at QL and J-values between QL and MDL) was most common, MDL-reporting (U-values at MDL and J-values between QL and MDL) was also used, especially in older data sets and for inorganic methods.

In addition, there were many different terms for the various limits. Besides quantitation limits, laboratories referenced reporting limits, detection limits, practical (or project) quantitation limits, and also an "adjusted" version of each that was adjusted for dilution factors, percent moisture, etc. For simplicity and consistency, CH2M required laboratories to reference the QL (lowest level of calibration) and MDL (statistically determined).

New-Style (DoD QSM v. 4.1) Reporting

Per DoD QSM v. 4.1, non-detect results are reported at the limit of detection (LOD) and results are qualified if they were detected at less than the limit of quantitation (LOQ). The laboratory may not report detections at less than the detection limit (DL).

The LOQ is identical to the old QL in that it is set at the lowest calibration standard. It should be noted that the LOQ must be at <u>a</u> calibration standard but need not be at <u>the lowest</u> calibration standard. The laboratory may set the LOQ for a particularly troublesome

analyte to a calibration standard higher than the lowest. As before, any detects reported at less than the LOQ (old QL) must be qualified as estimated.

The DL is similar to the old MDL in that it is typically thought of as the lowest concentration which is likely to be detected by the laboratory instrumentation. The DL is defined as "the lowest concentration or amount of the target analyte that can be identified, measured, and reported with confidence that the analyte concentration is not a false positive value" and is further clarified as "the smallest analyte concentration that can be demonstrated to be different from zero or a blank concentration at the 99% level of confidence. At the DL, the false positive rate (Type I error) is 1%" (DoD QSM v. 4.1). In fact, MDL studies are one common and acceptable way to determine DLs. Unrelated to DoD work, various states require that laboratories perform annual MDL studies. The laboratories are free to use their current MDLs as their DLs. Otherwise, the detection limit must be established using a scientifically valid and documented procedure.

The LOD is similar to the old "reporting limit" in that it is the level at which non-detect results are reported. The apparent signal-to-noise ratio at the LOD must be at least three and the results must meet all method requirements for identification. The LOD must be verified on each instrument that the laboratory may use to analyze samples. The LOD is a somewhat arbitrary level in that the laboratory has freedom to set it at some level based on the established DL and their experience. Guidelines for establishing an LOD are that it should be 2-3 times the DL for single analyte standards or 1-4 times the DL for multi analyte standards. Sometimes, laboratories elevate their LODs to match the LOQs and in these instances, non-detects are still technically reported at the LOQ which is identical to the old QL. LOD verifications are done immediately after establishing DLs and are then done quarterly. A failed LOD verification forces the laboratory to re-determine the DL and then repeat the LOD verification. LODs must be verified on each instrument that may analyze samples.

DoD QSM v. 4.1 clarifies that "the MDL is one way to establish a Detection Limit, not a Limit of Detection." DLs are instrument-specific and laboratories often use multiple instruments to analyze samples and report data. The advantage of using LODs for reporting versus DLs is that LODs are laboratory-specific, considering the DLs of the various instruments that may be used to analyze the samples.

Why New-Style is Better than Old-Style

Analytically, there are no differences between a given sample reported via QL/MDL and the same sample reported via LOQ/LOD/DL. The reporting differences are the numerical value associated with a non-detect result and the flagging assigned to a numerical result based on its proximity to the various limits. There are also subtle differences to the acceptance limits for associated laboratory QA/QC samples, since limits are often set to a fraction or a multiple of the LOQ or LOD. On the other hand, there are four distinct advantages to LOQ/LOD/DL reporting over QL/MDL reporting.

1. Because the DoD QSM v. 4.1 dictates the definition of these limits, their definitions are fixed and no longer ambiguous across laboratories. The LOQ, LOD, and DL are exactly what they are defined as in the DoD QSM v. 4.1, and all laboratories must use the same terminology.

2. Because the DoD QSM v. 4.1 dictates the reporting of results with respect to their proximity to these limits, laboratories are restricted to the appropriate protocol. Non-detects must be reported at the LOD. Non-detects may not be reported at the MDL. Results detected between the DL and LOQ must be qualified. Detections at less than the DL may not be reported.
3. DoD QSM v. 4.1 reporting acknowledges that the laboratory can "see" below the LOQ. It then forces the laboratory to prove that it can do so. A failure to verify LODs requires that the laboratory re-determine DLs and LODs. This in turn forces the laboratory to work within their analytical requirements and prevents them from reporting from a concentration range lower than they are capable.
4. The DoD QSM v. 4.1 protocol reduces the apparent uncertainty surrounding non-detect results where the QL is greater than the screening level. Selecting analytical methods based on their LODs will reduce the need for ultra-trace and specialty analytical services when standard analytical methods are perfectly appropriate. This will, in turn, reduce analytical expense.

Regulatory Review and Acceptance

The DoD QSM v. 4.1 is required for the analysis of environmental samples (generation of Definitive environmental data) to support the Department of the Navy, Department of the Army, Department of the Air Force, and the Defense Logistics Agency. The requirements and QC limits set forth in this document are minimum standards and may be overridden by contractor requirements, analytical method requirements, etc. <u>if more stringent</u>. In addition, the document is not intended to override host-nation, federal, state, or local regulations. The EPA, in particular, has not had the opportunity to review, provide comments on, and accept this document. However, the document is largely-based on NELAC requirements and the EPA-written SW-846 methods that it references to generate Definitive data. In addition, all project work plans written in UFP-SAP format (based on UFP-QAPP format) are populated using the applicable portions of the DoD QSM v. 4.1. Therefore, work plan sections based on the relevant portions of the DoD QSM v.4.1 are reviewed and approved by the regulatory agencies on a project-by-project basis. At this point, each stakeholder agency has the opportunity to provide comments and provide consensus with respect to the responses.