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GUIDE TO REPLACEMENT PAGES FOR SITE INSPECTION REPORT FOR MUNITIONS RESPONSE PROGRAM RANGES NSTC GREAT LAKES IL

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Guide to replacement pages

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VOLUME I

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SITE INSPECTION REPORT

MUNITION RESPONSE PROGRAM RANGES

NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

AA	Anti-Aircraft
bgs	Below Ground Surface
BL&P	Blind Loaded and Plugged
bss	Below Sediment Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CSM	Conceptual Site Model
CTO	Contract Task Order
°	Degree
%D	Percent Difference or Percent Drift
DERP	Defense Environmental Restoration Program
DI	Dark Ignition
DMM	Discarded Military Munitions
DoD	Department of Defense
DPT	Direct Push Technology
DQI	Data Quality Indicator
DQO	Data Quality Objective
ECO SSL	Ecological Soil Screening Level
ELAP	Environmental Laboratory Accreditation Program
EPA	Environmental Protection Agency
EPC	Exposure Point Concentration
ESS	Explosive Safety Submission
ER-L	Effects-Range Low
ER-M	Effects-Range Median
F	Fahrenheit
FBL	Fixed Base Laboratory
FD	Field Duplicate
FOL	Field Operations Leader
FS	Feasibility Study
FY	Fiscal Year

GC/MS	Gas Chromatograph/Mass Spectrometer
GIS	Geographic Information System
GPS	Global Positioning System
HASP	Health and Safety Plan
HE	High Explosive
HEI	High Explosive Incendiary
HEIT-SD	High Explosive Incendiary Tracer – Self Destruct
HET	High Explosive Tracer
HET-SD	High Explosive Tracer – Self Destruct
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HSM	Health and Safety Manager
IDW	Investigation-Derived Waste
INRMP	Integrated Natural Resources Management Plan
IS	Internal Standard
ITRC	Interstate Technology and Regulatory Council
LANT	Mid-Atlantic
LC	Liquid Chromatography
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LIMS	Laboratory Information Management Systems
LOEC	Lowest Observed Effects Concentration
MBE	Multibeam Echosounder
MC	Munitions Constituants
MDL	Method Detection Limit
MEC	Munitions and Explosives of Concern
mg/kg	Milligrams/Kilogram
mm	Millimeter
MPC	Measurement Performance Criteria
MPPEH	Material Potentially Presenting Explosive Hazard
MRP	Munitions Response Program
MRS	Munitions Response Site
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NA	Not Applicable
NAD83	North American Datum of 1983
NAVFAC	Naval Facilities Engineering Command

NAVSTA	Naval Station
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No Further Action
NG	Nitroglycerin
NIST	National Institute of Standards and Technology
NOEC	No Observed Effects Concentration
NOSSA	Naval Ordnance Safety and Security Activity
NSGL	Naval Station Great Lakes
NTC	Navy Training Center
OSHA	Occupational Safety and Health Administration
PA	Preliminary Assessment
PAH	Polycyclic Aromatic Hydrocarbon
PAL	Project Action Limit
PEC	Probable Effects Concentration
PETN	Pentaerythritol Tetranitrate
PID	Photoionization Detector
PM	Project Manager
POC	Point of Contact
PPE	Personal Protective Equipment
ppm	Parts Per Million
PQLG	Project Quantitation Limit Goals
QA	Quality Assurance
QAM	Quality Assurance Manager
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
QL	Quantitation Limit
QSM	Quality Systems Manual
RBSL	Risk-Based Screening Level
RCRA	Resource Conservation and Recovery Act
%R	Percent Recovery
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RF	Response Factor
RI	Remedial Investigation
RPD	Relative Percent Difference
RSD	Relative Standard Deviation

R-RSL	Residential – Regional Screening Level
RTK	Real Time Kinematic
RV	Recreational Vehicle
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SDG	Sample Delivery Group
SDZ	Safety Danger Zone
SI	Site Inspection
SIM	Selected Ion Monitoring
SOP	Standard Operating Procedure
SSC	Service School Command
SSL	Soil Screening Level
TACO	Tiered Approach to Corrective Action Objectives
TBD	To Be Determined
TCLP	Toxicity Characteristic Leaching Procedure
TEC	Threshold Effects Concentration
TEF	Toxicity Equivalency Factor
Tetra Tech	Tetra Tech NUS, Inc.
Tetryl	N-methyl-N-2,4,6-tetranitroaniline
TNT	Trinitrotoluene
TSA	Trap, Skeet, and Archery
UCL	Upper Confidence Limit
UFP	Uniform Federal Policy
USBL	Ultra Short Acoustic Baseline Positioning System
USEPA	United States Environmental Protection Agency
U.S.C	United States Code
UV	Ultraviolet
UXO	Unexploded Ordnance
WAMS	Water Area Munitions Study
WWII	World War II
XRF	X-ray Fluorescence Spectrometer

EXECUTIVE SUMMARY

Tetra Tech NUS, Inc. (Tetra Tech) has prepared this Site Inspection (SI) Report under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-03-D-0057, Contract Task Order (CTO) F274. This report has been prepared for a SI for Munitions Constituents (MC) under the Munitions Response Program (MRP) at four Munitions Response Sites (MRSs) located at Naval Station Great Lakes (NSGL), Great Lakes, Illinois. The MRP sites included in the scope of this SI are the former Trap, Skeet, and Archery (TSA) Ranges; the former Pistol Butts; the former Machine Gun Range; and the former Naval Training Center (NTC) Lakefront anti-aircraft (AA) Range (NTC Lakefront). Figure ES-1 presents a Site Location Map depicting the location of the four MRSs on the NSGL installation. The MRSs are described briefly below.

The U.S. Department of Navy (Navy) has conducted various testing and training activities involving military munitions at the MRSs. Because of these activities, Munitions Constituents (MC) and Munitions and Explosives of Concern (MEC)/material potentially presenting an explosive hazard (MPPEH) may be present at one or more of these locations. The term MC includes constituents associated with munitions such as metals and nitroglycerin (NG). The term MEC includes Discarded Military Munitions (DMM), Unexploded Ordnance (UXO), and MC in high enough concentrations to pose an explosive hazard. The Department of Defense (DoD) has established the MRP to address MC and MEC environmental concerns at closed ranges. The DoD is following the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) process for the investigation and remediation of these sites. The Navy is responsible for implementing the MRP at NSGL.

The four MRP SIs at NSGL were inspected to determine the nature of the potential hazards associated with MC and/or MEC linked to past on-site training activities. This SI Report documents the results of field activities and the current conceptual site models (CSMs) for each area of concern. Table ES-1 and ES-2 summarize the results of the MC and MEC SI investigations, respectively. This collected data was used to approximate site boundaries, collect broad site information, and assess the potential hazards posed by any MC and/or MEC/MPPEH remaining at a site in order to support the final site recommendations. The SI augmented the data collected in the Preliminary Assessment (PA) Reports and Water Area Munitions Study (WAMS) investigation phases prepared by Malcolm Pirnie in 2005 and 2008, respectively; and generated field data to determine if further response action or remedial investigation (RI) is appropriate. However, this MC SI investigation was not intended as a full-scale study of the nature and extent of MC or MEC/MPPEH hazards, but was intended to confirm the absence of significant MC and/or MEC/MPPEH.

The investigation samples were analyzed for MC potentially associated with historical training activities at each site using a combination of on-site field analyses for lead and off-site fixed-base laboratory (FBL) analyses for lead (to confirm the on-site lead results) and other constituents.

TSA Ranges

The former TSA Ranges site encompasses approximately 30.5 acres, including the land and water portions. The land portion consists of approximately 1.1 acres of Lake Michigan beachfront, which included the former firing arcs for the skeet and trap ranges and all associated structures. Fill material was added to the beachfront to extend the shoreline for the addition of the skeet range. The water portion of the TSA Ranges, where munitions were fired, includes the maximum extent of shotfall, which is approximately 29.4 acres. Munitions use was limited to small arms ammunition, primarily shotgun ammunition. The land and water portions are not suspected to contain MEC; therefore, no MEC investigation is planned for the TSA Range. The land portion has been redeveloped as a recreational vehicle (RV) park, leaving no evidence of the TSA Ranges. There are no records of previous sampling events. This SI focused on both the land and water portions of the TSA Ranges. For the land portion, surface soil samples were collected and analyzed on-site for lead using X-ray fluorescence (XRF) and off-site for polynulcear aromatic hydrocarbons (PAHs) and select metals (arsenic and lead). For the water portion, sediment samples were collected and analyzed off-site for PAHs and select metals (antimony, arsenic, and lead). Figure ES-2 depicts the TSA Ranges and associated range features.

Pistol Butts

The former Pistol Butts site is located in a flat area of the NSGL Outer Harbor shoreline, south of the installation's former wastewater (sewage) treatment plant, and is approximately 4 acres in size. The site boundary on the west is an approximately 50-foot high bluff, and on the east is Lake Michigan. Currently, the northern end of a concrete retention pond and paved roadway southwest of the landing craft storage building (see Figure ES-3) cover the site. There is no evidence of the Pistol Butts remaining on the surface of NSGL. There are very limited records available on the history of this site, which only appears on one 1909 archival map provided in Appendix A of the UFP-SAP (Tetra Tech, 2010). The 1909 archival map indicates that the firing line was located immediately west of a former seawall that is located at the edge of Lake Michigan. Individual firing lines were not noted on the map; however, the firing lane lengths were estimated at approximately 40 yards. The former firing points and range floor are currently covered by a concrete retention pond, vegetation (grass strip), and a roadway. The location of the former pistol range bullet stop/butt (the natural bluff to the west of the site) appears to have been buried during

redevelopment. Therefore, subsurface soil sampling was conducted at the suspected bullet impact (former Pistol Butts) area to depths below the fill thickness. Because it is believed that only small arms training occurred at this site, MEC would not be expected to be present at a pistol range. Therefore, no MEC investigation occurred at the former Pistol Butts site. The SI focused on the buried bullet stop/butt area where subsurface soil samples were collected and analyzed on-site for lead using XRF and off-site at the FBL for select metals (antimony, arsenic, and lead).

Machine Gun Range

The former Machine Gun Range site is located immediately south of Building 13 (the Boat House) and the manmade boat channel entering in the harbor in the southern portion of the installation. The range was used for the training of naval personnel on small arms of .50-caliber or less. Based on the 1905, 1915, and 1918 archival maps, it appears that targets were located on the inner breakwater of the harbor and were fired upon from a 200- and 300-yard firing line on land; therefore, this range contains land-based firing locations and an impact area in Lake Michigan. A paved roadway and an area for landing craft storage now cover the majority of the site. The SI focused on the land portion of the site where surface soil samples were collected and analyzed off-site at the FBL for select metals (antimony, arsenic, and lead) and select propellants (nitroglycerine (NG). Additionally, the SI focused on the water portion or target area immediately in front of the breakwater where sediment samples were collected and analyzed off-site at the FBL for select metals (antimony, arsenic, and lead). Figure ES-4 depicts the Machine Gun Range site features. Because only small arms were used at this site, MEC would not be expected to be present at the Machine Gun Range. Therefore, no MEC investigation was conducted for this site.

NTC Lakefront

The former NTC Lakefront Site was a 3,728 acre AA range and target training area located on the eastern edge of the NSGL (3.3-acre portion of beachfront along Lake Michigan and the remaining 3,725 acres extending east over Lake Michigan). Potential MC issues are associated with the use of AA ammunition are tracers [20-millimeter (mm) high explosive (HE), high explosive incendiary (HEI), high explosive tracers (HET), and HET-dark ignition (DI) rounds, 40-mm blind loaded and plugged (BL&P), high explosive tracer – self destruct (HET-SD), and high explosive incendiary tracer – self destruct (HEIT-SD) rounds, 1.1-inch AA artillery, 3-inch 0.50-caliber artillery, and DI tracers]. The AA gun mounts were located on fill material along the shoreline and aimed at targets towed by plane with cables over Lake Michigan. Approximately 1,350 sailors per day were instructed on the 20- and 40-mm guns during AA training exercises and several million rounds were fired into Lake Michigan during the existence of the range. The NTC Lakefront Preliminary Assessment (PA) Report indicated that only AA ammunition was

used at the range. The expected dud rates of the types of AA ammunition used was five percent resulting in several hundred thousand rounds containing explosives, which may be present in Lake Michigan sediment.

The land portion of the site is currently paved and is bordered by an RV park, is used for the storage of fuel oil for the facility's power plant, and is not suspected for the presence of MC or MEC. Due to the paved roadway covering the location of the former gun mounts and high rates of erosion and deposition immediately in front of the gun mounts, MC sampling did not occur at the former firing line. However, the water portion of the site has a potential that MEC and associated MC is present within the sediment in Lake Michigan. The MC SI focused on the lake sediment in close proximity to potential MEC/MPPEH identified during the MEC SI, which focused on a nonintrusive geophysical investigation discussed in Volume II of the SI Report.

The performance of a multi-beam echosounder (MBE) survey to determine the bathymetry of the lake bottom and a marine gradiometer array (MGA) survey to identify magnetic anomalies, which may represent MEC/MPPEH, was conducted prior to the MC SI. These surveys identified bands of magnetic material located in the Lake Michigan sediment, which were used to identify MC sampling locations throughout the surface danger zone (SDZ).

The MC SI focused on the water portion of NTC Lakefront where sediment samples were collected and analyzed off-site for select explosives [octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), trinitrotoluene (TNT), N-methyl-N,2,4,6-tetranitroaniline (tetryl), and pentaerythriotol tetranitrate (PETN)] and select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc). Figure ES-5 depicts the NTC Lakefront site features.

CONCLUSIONS AND RECOMMENDATIONS

This section presents a summary of the results of the SI and recommendations for further actions. Table ES-1 presents a summary of the MC SI Investigation, and Table ES-2 presents a summary of the MEC SI Investigation.

CONCLUSIONS - TSA RANGES

- The environmental data collected during the SI sampling activities are sufficient to determine the presence or absence of MC associated with the former use of the ranges in the soil and sediment.

- The focused SI sampling activities for the TSA Ranges characterized the local site conditions in surface soils [0 to 0.5 feet below ground surface (bgs)] and sediment [0 to 0.5 feet below sediment surface (bss)].

- The SI identified concentrations of MC associated with small arms ammunition in surface soil and sediment.

- The SI identified MCs (lead and PAHs) at concentrations above project action limits (PALs) and their Illinois EPA background concentrations in a limited surface soil area collected from the TSA Ranges.

- The SI identified MCs (antimony and lead) at concentrations above ecological PALs and their Illinois EPA background concentrations in the sediment samples in a limited area collected from the TSA Ranges.

RECOMMENDATIONS - TSA RANGES

Soil

- Further actions are required at the site based on the SI identification of lead and PAH concentrations greater than respective PALs and the Illinois EPA background soil concentrations in surface soil within the project site at a limited area in the TSA Ranges.

Sediment

- Further action is recommended for sediment because sediment concentrations for lead exceed its respective ecological PAL for aquatic biota. However, the potentially impacted area associate with the sediment near the shore within the TSA Ranges is relatively small and impact from the lead concentrations appear to be insignificant. Further evaluation of ecological risks is warranted and recommended.

CONCLUSIONS – PISTOL BUTTS

- The environmental data collected during the SI sampling activities are sufficient to determine the presence, or absence, of MC associated with the former use of the range in the subsurface soils.

- All laboratory lead detections were less than the Human Health PAL (400 mg/kg).

- Antimony was not detected above the laboratory detection limit in any of the samples for the Pistol Butts site.

- The soil samples submitted for laboratory analyses exhibited concentrations of arsenic exceeding the Human Health PAL (0.39 mg/kg) but were below the Illinois EPA Tiered Approach to Corrective Action Objectives (TACO) soil background concentrations (13 mg/kg). Therefore, it has been determined that the concentrations of arsenic detected in the soil samples collected from the Pistol Butts site are not indicative of MC associated with the historical range activities conducted at the site.

RECOMMENDATIONS – PISTOL BUTTS

- NFA at the Pistol Butts site is recommended based on the SI sampling results.

CONCLUSIONS – MACHINE GUN RANGE

- The environmental data collected during the SI sampling activities are sufficient to determine the presence or absence of MC associated with the former use of the ranges in the soil and sediment.

- The focused SI sampling activities characterized the local site conditions and identified concentrations of MC associated with small arms ammunition in surface soil and sediment.

- MCs (arsenic and lead) were identified at concentrations above their respective PALs in the surface soil of the Machine Gun Range.

- None of the soil samples submitted for laboratory analyses exhibited lead concentrations exceeding the Human Health PAL (400 mg/kg), but there were exceedances of the ecological PAL (11 mg/kg).

- All of the arsenic soil samples submitted for FBL analyses exhibited arsenic concentrations exceeding the Human Health PAL (0.39 mg/kg)

- No lead sample concentration exceeded the TACO construction worker ingestion criteria (61 mg/kg).

- No arsenic sample concentration exceeded of the ecological PAL (18 mg/kg) or concentrations above the Illinois EPA soil background concentration (13 mg/kg).

- None of the soil samples exhibited concentrations above the respective PALs for antimony and NG.

- Ten sediment samples were collected from 10 discrete locations at depths of 0 to 0.5 feet bss within Lake Michigan.

- All 10 of the sediment samples submitted for FBL analyses exhibited lead concentrations exceeding the ecological PAL (35.8 mg/kg).

- Two of the sediment samples submitted for laboratory analyses exhibited arsenic concentrations exceeding the ecological PAL (9.79 mg/kg).

- Both lead and arsenic concentrations were statistically above site-specific upgradient/background sediment concentrations.

- None of the sediment samples had detected concentrations above the antimony Human Health PAL (0.39 mg/kg).

RECOMMENDATIONS – MACHINE GUN RANGE

Soil

- Further action is recommended for soil because concentrations for lead and arsenic exceed their respective ecological PALs for terrestrial biota. However, the potentially impacted area is relatively small, and impact to terrestrial ecological receptors appears to be insignificant. Further evaluation of ecological risk is warranted and recommended.

Sediment

- Further action is recommended for sediment because concentrations of lead and arsenic exceed their respective ecological PALs for aquatic biota. However, the potentially impacted area is relatively small and impact to aquatic biota appears to be insignificant. Further evaluation of ecological risk is warranted and recommended.

CONCLUSIONS – NTC LAKEFRONT

- Arsenic was the only metal that exhibited concentrations in excess of its ecological PAL in the sediment samples collected from NTC Lakefront.

- The levels of arsenic detected within the SDZ of the site were statistically below the arsenic concentrations detected in the upgradient (background) site-specific sediment samples.

- The arsenic observed within NTC Lakefront can be attributable to naturally occurring arsenic concentrations found within the lake.

- Detection limits for several explosive constituents (HMX, RDX, and TNT) are similar to or much lower than No Observed Effects Concentrations (NOEC) based on more recent empirical data. Therefore, impacts to sediment invertebrates from explosive constituents are not expected.

- No surface MEC was identified during the SI.

- Numerous anomalies, potentially MEC/MPPEH, were detected during the performance of the magnetic marine survey

RECOMMENDATIONS – NTC LAKEFRONT

Based on the results of the SI, further action is recommended for explosives and NFA is recommended for select metals for NTC Lakefront.

Further action will be necessary to ascertain whether magnetic anomalies identified during the underwater geophysical survey are MEC/MPPEH as part of an RI.

Additional geophysical investigation may be required to fully delineate the horizontal extent of magnetic anomalies north and south of the current range fan.

If anomalies are determined to be MEC/MPPEH, then biased MC samples should be collected at these locations for select metals and explosive analytes. In this event, an alternate explosive analytical method using mass spectral detectors should be used. The method should incorporate LC with a mass spectral detector due to its ability to determine the presence of low-level explosives constituents with a higher degree of certainty than the LC method with ultra violet (UV) detector.

TABLE ES-1

SUMMARY OF FINDINGS AND RECOMMENDATIONS
SITE INSPECTION REPORT - MC EVALUATION
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Site Name/Subareas	PAL Screening Exceedance	Contaminant(s) of Potential Concern	Background/Risk Screening Evaluation	Recommendation
TSA Ranges				
Surface Soil	YES	Lead, PAHs, Arsenic, Antimony	**Lead** - Average concentrations above TACO background level; **PAHs** - concentrations above TACO backround levels; **Arsenic** - concentrations below TACO backround levels; **Antimony** - concentrations below TACO backround levels	Proceed to RI for Lead and PAHs in soil.
Sediment	YES	Lead, Antimony	**Lead** - concentrations above ugradient/background levels, but ecological risk is insignificant	Proceed to further action - ecological risk assessment of lead and antimony in sediment.
Pistol Butts				
Subsurface Soil	YES	Arsenic	**Arsenic** - concentrations below TACO backround level	NFA
Machine Gun Range				
Surface Soil	YES	Lead, Arsenic, Antimony	**Lead** - Only ecological PAL exceedances, average concentrations above TACO background level, but ecological risk appears insignificant; **Arsenic** - concentrations below TACO backround levels; **Antimony** - concentrations below TACO backround levels	Proceed to further action - ecological risk assessment of lead in soil
Sediment	YES	Lead, Arsenic	**Lead** - concentrations above ugradient/background levels, but ecological risk appears insignificant; **Arsenic** - concentrations above ugradient/background levels, but ecological risk appears insignificant;	Proceed to further action - ecological risk assessment of lead and arsenic in sediment.
NTC Lakefront				
Sediment	YES	Arsenic, Explosives (HMX, RDX)	**Arsenic** - concentrations below site-specific upgradient/background level; **HMX, RDX, and TNT** - concentrations of explosive constituents are lower than NOECs; therefore, impacts to sediment invertebrates are not expected.	NFA for MC. Further action recommended for MEC.

TACO - Illinois EPA soil background concentration (Illionois EPA, Appendix A, Table G)
NFA = No further action
PALs = Project action limits
RI = Remedial Investigation

4.0 TSA RANGES

4.1 SITE BACKGROUND

The former TSA Ranges (including the land and water portions) encompasses approximately 30.5 acres. The land portion of the TSA Ranges is a small area (approximately 1.1 acre), located east of the bluff on the beachfront of Lake Michigan. The site consisted of a trap range, a skeet range, and an archery range. Only the skeet and trap ranges are the subject of this SI. Fill material was placed at the site to extend the shoreline for the addition of the skeet range to the installation. Structures associated with the skeet and trap ranges and firing lines were located on the land. The shotfall zone, which is defined as the maximum extent that lead shot would travel extends into Lake Michigan. This encompasses an area of approximately 29.4 acres [consisting of overlapping areas for the skeet range (29 acres) and the trap range (6.6 acres)] located over Lake Michigan, as shown on Figure 4-1. The site originally consisted of only the trap range (constructed in the early 1940's), which was used in conjunction with the NTC Lakefront for Navy personnel to first experience targeting a moving object before handling the large caliber AA guns. The use of the trap range in conjunction with the AA training center ended with the closing of the NTC Lakefront site in October 1945; however, the trap range was likely used recreationally afterward, as it was common practice to allow enthusiasts to enjoy these ranges to offset costs for maintenance. Based on the construction drawings for the site, the skeet and archery ranges were added to the site in 1968 and were likely used for recreational purposes and for military practice sessions. Munitions use was limited to small arms ammunitions, primarily shotgun ammunition.

The equipment storage building and trap/skeet houses that were originally located at the site were demolished, and the ranges were decommissioned. Construction of a recreational vehicle (RV) park in July 2000 (RV sites, 10 tent sites, and one group camping site) within the TSA Ranges removed all visible signs of the ranges and associated structure, such as the trap house. No prior site investigations have been conducted at the NSGL TSA Ranges.

Figure 4-1 depicts the TSA Ranges and associated range features.

4.1.1 Historical Munitions Usage Information

Archival data for ammunition orders from the 1940s and 1950s included the following munitions-related items that may have been used at the site:

- Shotguns, 12-gauge with slide repeating action and modified choke, 26-inch or 28-inch barrel.
- Shells, shotgun, 12-gauge, No. 7 ½ shot.
- Targets, clay pigeon.

During the 2008 visual survey of the site by Malcolm Pirnie, no physical evidence of the skeet range firing arc and trap range firing points/stations was visible due to the construction of the RV park. Additionally, no evidence of broken clay targets was observed during the site walk. However, during the SI sampling activities, broken clay targets and shotgun shell wadding were observed in the surface soils of the erosional surface near the shoreline of the Trap Range. The TSA Ranges was dedicated to the use of small arms; therefore, MEC is not expected to be present at the site. In addition, based on the information obtained during the data collection process, no special consideration munitions are known or suspected to have been used at the site. Therefore, the TSA Ranges is not suspected to contain chemical warfare material filled munitions, electrically fuzed munitions, or depleted uranium associated munitions.

4.1.2 Munitions Constituents

For shotgun ammunition and clay targets, the primary MC of concern include lead from shot and PAHs from pitch tar used in the manufacturing of clay pigeons to help bind the clay particles. Other associated MC less likely to be of concern may include antimony and arsenic (which may be present in lead). Lead accounts for more that 95 percent of the weight of the projectile (ITRC, 2003). Antimony is added to bullets as a hardening agent in quantities ranging from 0.1 to 2 percent. Arsenic is naturally present in lead at trace levels (0.001 to 0.06 percent). Antimony and arsenic, if present, would be spatially correlated with the lead because they are associated with lead in the bullets. The USEPA screening value commonly used to indicate the presence of potentially unacceptable levels of antimony in soil and sediment is 31 mg/kg; the screening value for arsenic is 0.39 mg/kg and is within the typical soil background concentrations according to TACO of 13 mg/kg. Using the relative concentrations of these metals in projectiles, lead would have to be present in soil or sediment at a concentration greater than 600 mg/kg for arsenic or antimony from bullets to be present at potentially unacceptable levels for effects on human health. Therefore, lead, which is easier to measure in some prospects, is a useful indicator of potentially unacceptable concentrations of any of these five metals in soil or sediment. These MC components are not consumed when the munitions items function as they are designed. Therefore, these MC may exist at the TSA Ranges.

4.2 SITE FIELDWORK

4.2.1 Site Field Activities

The SI field program for the TSA Ranges included collection of surface soil samples (0 to 0.5 foot bgs) on the land portion of the site, and sediment samples (0 to 0.5 feet below sediment surface [bss]) from the area of the site within Lake Michigan to identify contaminants of potential concern (COPCs) (e.g., select metals and PAHs) that may exist as a result of past operations at the ranges. Soil and sediment sample log sheets are included in Appendix A. Photographs associated with the sampling activities at the TSA Ranges are presented in Appendix B.

Surface Soil Sampling

Table 4-1 lists the soil samples that were collected at the TSA Ranges. All surface soil samples were analyzed in the field utilizing XRF with a subset of those samples selected for submittal to the FBL for select metals analysis (lead, antimony, and arsenic). All sediment samples were submitted to the FBL for PAH and metals analysis. A correlation study comparing XRF and the FBL analytical data was completed after the field efforts to establish laboratory equivalent lead concentrations based on the field measurements, and to use as a correlation analysis between XRF and the FBL lead concentrations. This correlation is discussed in Section 4.5.

Soil sample locations were selected based on a bias toward areas that were believed to be most likely contaminated by past operations at the site. Figures 4-2 and 4-3 present the surface soil sample locations for the Trap Range and Skeet Range areas of the TSA Ranges, respectively. Prior to initiating sample collection, all terrestrial sample locations were marked by brightly colored pin flags bearing the sample location ID number. Sample locations identified in the approved UFP-SAP were located using a Trimble GeoHX sub-meter GPS unit. Upon collection of all the samples at the ranges, the GPS was used to update the sample coordinates using the horizontal datum: NAD 83 Illinois State Plane Coordinate System east.

Sediment Sampling

Table 4-1 includes the sediment samples that were collected at the TSA Ranges. As part of the SI sediment sampling event for the TSA Ranges, 18 sediment samples were collected from within Lake Michigan. Figures 4-2 and 4-3 present the sediment sample locations for the Trap Range and Skeet Range sites, respectively.

4.2.2 Work Plan Deviations

The only deviation from the UFP-SAP (Tetra Tech, 2010) for the TSA Ranges SI was that of the proposed 60 soil samples to be field analyzed by XRF, only 57 samples were able to be collected and analyzed due to three sample being composed of only coarse sand and gravel from the small beach area near the surf zone. Therefore, there was no soil associated with samples NTC-SD-TSA-054 through NTC-SD-TSA-056 and they were not analyzed by XRF for the site.

4.2.3 Field Data Collection

Surface Soil

Fifty-seven discrete surface soil samples were collected from 57 sample locations during the SI at the TSA Ranges in accordance with SOP-05 of the UFP-SAP. Sample locations were selected based on a spatial grid pattern to cover the land portion of the site immediately in front of the former firing arch and firing point for the trap and skeet ranges. A 0 to 0.5-foot bgs sample was collected at each sample location with the use of a hand auger. All samples underwent field XRF analysis for lead in accordance with SOP 10 of the UFP-SAP, and 20 samples were subsequently chosen for select metals (antimony, arsenic, and lead) analyses at the FBL by Method SW-846 6010B. In addition, the same 20 samples were submitted for PAH analyses by Method SW-846 8270C SIM. All samples chosen for metals laboratory analysis were selected from samples having an XRF lead concentrations greater than 100 parts per million (ppm).

All samples for metals analyses were placed in large Ziploc® bags and thoroughly homogenized prior to processing a portion for XRF analysis. For samples selected for laboratory analysis, a portion of the sample was placed in the appropriate sample jar and shipped to the FBL for select metals analyses.

Sediment

Sediment samples were collected in accordance with SOP-06 and SOP-08 of the UFP-SAP. A total of 18 sediment samples were collected from Lake Michigan for the TSA Ranges. Seven near shore shallow water (less than 6 feet) sediment samples, and six deep water (greater than 6 feet) sediment samples were collected for the Skeet Range area. Five deep water sediment samples were collected for the Trap Range area. The shallow water sediment samples were collected using a petite Ponar dredge from a Zodiac™ inflatable boat. The deep water sediment samples were collected using a modified pneumatic Van Veen dredge from a survey vessel.

All sediment samples were submitted to the FBL for laboratory analyses of select metals (antimony, arsenic, and lead) by Method SW-846 6010B and PAHs by SW-846 8270C SIM.

Table 4-1 provides a summary of the samples collected and their respective analysis at the TSA Ranges. Figures 4-2 and 4-3 show the soil sampling and sediment sampling locations for the Trap Range area and Skeet Range area, respectively. Soil and sediment sample log sheets are included in Appendix A of this document.

Upgradient Sampling Locations

Three discrete sediment samples (SD-UPG001 through SD-UPG003) were collected at sample locations upgradient (north) of the surface danger zone (SDZ) of the TSA Ranges and seven discrete samples (LAK-UPG004 through LAK-UPG010) were collected upgradient (north) of the SDZ of the NTC Lakefront using the modified pneumatic Van Veen sampling method. All 10 sediment samples were submitted to the laboratory analysis for select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) by method SW-8946 6010B and three samples for PAHs analyses by Method 8270C. Figure 4-4 shows the upgradient sediment sampling locations for the TSA Ranges.

4.3 SITE INSPECTION DATA COLLECTION RESULTS

4.3.1 MC Sampling Results

Soil and sediment samples collected at the TSA Ranges were compared to respective PALs as listed in Worksheet #15 of the UFP-SAP (Tetra Tech, 2010). The chemical reference limits and background evaluation table and the complete validated FBL data tables are presented in Appendix D.

Table 4-2 summarizes the XRF lead results for the surface soil samples collected at the TSA Ranges. The lead PAL for the FBL analyses is 400 mg/kg, and was based on the Illinois EPA residential Tier 1 soil remediation objectives. The project field screening level for the field XRF analyses was 100 mg/kg, which was selected as a conservative measure and is one-quarter of the Illinois EPA residential Tier 1 soil remediation objective.

Tables 4-3 and 4-4 present the metals (antimony, arsenic, and lead) and PAH detections in the soil and sediment samples at the TSA Ranges, respectively. The data comparison to PALs is discussed in Section 4.6. Figures 4-5 and 4-6 present the select metals (antimony, arsenic, and lead) detections in the soil samples at the Trap Range and Skeet Ranges areas of the TSA Ranges, respectively. Figures 4-7

and 4-8 present the PAH detections in the soil samples at the Trap Range and Skeet Ranges, respectively. Figure 4-9 presents the select metals (antimony, arsenic, and lead) exceedances in the sediment samples at the TSA Ranges.

4.4 DATA PRESENTATION/DATA USABILITY

4.4.1 Data Quality Review of Samples at the TSA Ranges

This section contains a description of the data review processes used to determine whether analytical laboratory data collected during the sampling field effort for the TSA Ranges were of acceptable quality for use in decision-making. The review began with data validation, which is a comparison of DQIs against the prescribed acceptance criteria. The DQIs are measures used to assess the completeness, sensitivity, accuracy, precision, comparability, and representativeness of the sample collection and sample analysis process. The output of this review was a set of alphabetic flags such as "U," "J", "R," or combinations thereof, assigned to individual results based on the validation effort. These flags were used to infer the general quality of the data and if data quality meets the data quality objectives (DQOs) of the project. The DQOs presented in the approved UFP-SAP (Tetra Tech, 2010) were maintained through the course of the sampling event. Worksheets #15 and #19 of the UFP-SAP present the analytical methods and compounds analyzed.

4.4.1.1 Data Validation Process

All of the FBL sample results were validated according to several specifications. Assignment of data qualification flags conformed to rules established in USEPA National Functional Guidelines for Organic Data Validation (October 1999), USEPA National Functional Guidelines for Inorganic Data Validation (October 2004), and Department of Defense (DoD) document entitled Quality Systems Manual (QSM) for Environmental Laboratories (January 2006 and April 2009) to the greatest extent practicable for non-contract laboratory program data.

Several samples analyzed for various parameters were qualified due to numerous issues. Appendix D contains the data validation reports, which outline the specific qualification reasons for each sample according to the parameter.

4.4.1.2 Data Quality Review

Some of the DQIs are generated from the analysis of field samples (e.g., field duplicates) while others are from the analysis of FBL samples (e.g., laboratory duplicates). Individually, field and FBL DQIs provide

measures of the performance of the respective investigative operations (field or laboratory). If individual QC results were unacceptable, there was an assignment of a validation flag indicating the type of QC deficiency impacting the result. Supporting documentation regarding the data presentation and usability for the TSA Ranges is presented in Appendix E.

4.4.1.3 Completeness

The field XRF field screening of surface soil was 95 percent complete. The surface soil and sediment FBL sample collection and FBL analytical completeness for the TSA Ranges were 100 percent.

4.4.1.4 Sensitivity

The Project Quantitation Limit Goals (PQLGs) for each analyte were listed in Worksheet #15 of the UFP-SAP (Tetra Tech, 2010). Analytical sensitivity for the TSA Ranges data was satisfactory to meet the DQOs presented in the UFP-SAP.

4.4.1.5 Field and Laboratory Accuracy

There were no QC deficiencies noted for field or FBL precision for the TSA Ranges.

4.4.1.6 Field and Laboratory Precision

The PAH compounds 2-methylnapthalene, acenaphthene, anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, naphthalene, and phenanthrene were qualified due to field duplicate imprecision for the field duplicate pair of sample TSA-053 because of noncompliant relative percent differences (RPDs) ranging from 53 to at most 200 percent. Fluoranthene was qualified due to field duplicate imprecision for the field duplicate pair of sample TSA-059 because of a noncompliant RPD of 72 percent. Benzo(a)pyrene was qualified due to field duplicate imprecision for the field duplicate pair of sample TSA-074 because of a noncompliant RPD of at least 200 percent.

No data was qualified due to laboratory duplicate imprecision.

4.4.1.7 Comparability

Comparability is defined as the confidence with which one data set can be compared with another (e.g., among sampling points and among sampling events). Comparability was achieved by using standardized sampling and analysis methods, as well as standardized data reporting formats.

Comparability of laboratory measurements was achieved primarily through the use and documentation of standard sampling and analytical methods. Results were reported in units that ensured comparability with current state and federal standards and guidelines. Comparability of laboratory measurements was assessed primarily through the use of QC samples and through adherence to the quality assurance (QA) plan. The data comparability for the TSA Ranges was deemed acceptable.

4.4.1.8 Representativeness

The UFP-SAP (Tetra Tech, 2010) and the use of standardized sampling, sample handling, sample analysis, and data reporting procedures were designed so that the final data would be accurate representations of actual site conditions. Based upon the field logs indicating the conditions during sample collection and FBL audits, all reported data are adequately representative of site conditions of the TSA Ranges.

4.5 LEAD CORRELATION BETWEEN FIELD XRF ANALYSIS AND FBL

All soil samples collected from the TSA Ranges were analyzed with XRF, with the exception of three samples, which had no soil remaining after removing the coarse sand and gravel. At the Trap Range, six of the 20 surface soil samples analyzed in the field with XRF had average lead concentrations exceeding the field screening level of 100 mg/kg, with concentrations ranging from 115 to 146 mg/kg (Table 4-2). These six samples were sent to the FBL for lead analysis. The highest concentrations of lead in the Trap Range were located in the area closest to the shoreline. No lead shot was observed in the samples; however, fragments of clay pigeon and shotgun shell wadding were visually observed during the SI field activities in this area of the site. Fragments of clay pigeon and shotgun shell wadding were removed from the soil sample prior to conducting the XRF lead analysis.

At the Skeet Range, 14 of the 37 soil samples analyzed in the field with XRF had average lead concentrations exceeding the field screening level of 100 mg/kg, with concentrations ranging from 24 to 468 mg/kg (Table 4-2). The highest concentrations of lead were located in the area closest to the firing line of the range.

From the samples that were analyzed in the field using XRF and at the FBL, a regression analysis was conducted to evaluate the correlation between the FBL lead results and XRF lead results. To evaluate the regression analysis, the Pearson Correlation and the R-squared value were calculated. The Pearson Correlation is a measure of the strength of the linear relationship between two or more variables with a range of -1 to +1. The value of -1 represents a perfect negative correlation (as one variable decreases

the other increases proportionally); whereas, a value of +1 represents a perfect positive correlation (as one variable increases the other increases proportionally). A value of 0 represents a lack of correlation.

The correlation between the XRF and FBL concentrations is -0.017 and the corresponding R^2 value is 3E-4. The correlation indicates a weak linear relationship. Therefore, the correlation between the XRF and FBL is not acceptable as outlined by the UFP-SAP. FBL concentrations cannot be predicted from XRF concentrations for the TSA Range. The regression analysis is presented in Appendix F.

4.6 DATA COMPARISON TO PROJECT ACTION LIMITS

4.6.1 Identification of Chemicals Exceeding Project Action Limits

Twenty of the 57 surface soil samples collected from the TSA Ranges were submitted to the FBL for select metals (arsenic, antimony, and lead) and PAH analysis. Six surface soil samples were selected from the Trap Range area of the TSA Ranges (TSA-015 through TSA-018, TSA-059, and TSA-060), and 14 soil samples were selected from the Skeet Range area of the TSA Ranges (TSA-020, TSA-021, TSA-023, TSA-028, TSA-030, TSA-031, TSA-038, TSA-039, TSA-041, TSA-044, TSA-050 through TSA-053). Additionally, six sediment samples from the Trap Range area (TSA-061 through TSA-066), and 12 sediment samples from the Skeet Range area (TSA-067 through TSA-078), were submitted to the FBL for select metals and PAH analysis.

The laboratory concentrations for the surface soil samples were compared to both the human health-derived PAL and the ecological-derived PAL for screening purposes to determine if further investigation is necessary. In addition, the Illinois EPA Tiered Approach to Corrective Action Objectives (TACO) area soil background concentrations for each metal and PAH were listed in the table for comparison purposes. All of the soil samples collected from the TSA Ranges were surface samples (0 to 0.5 feet bgs).

The laboratory concentrations for the sediment samples were compared to the ecological PAL for screening purposes to determine if further investigation is necessary. In addition, the data was compared to the site-specific background sediment sample concentrations for select metals and PAHs for evaluation purposes. All of the sediment samples collected from the TSA Ranges were collected 0 to 0.5 feet below the sediment surface (bss) of the lake.

Tables 4-3 and 4-4 summarize the laboratory analytical detection results as compared to the PALs for the TSA Ranges' surface soil and sediments samples, respectively. If a parameter exceeded its respective PAL in any sample, the parameter was highlighted (human health) or bolded (ecological). The parameter

was highlighted and bolded if the concentration exceeded both the human health and the ecological screening criteria for the soil data.

Three discrete sediment samples (SD-UPG001 through SD-UPG003) were collected at sample locations upgradient (north) of the SDZ of the TSA Ranges. All three sediment samples were submitted to the laboratory for select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) and PAHs analyses. Concentrations of select metals and PAHs in the upgradient sediment samples were compared to the sediment samples collected within the TSA Range area for evaluation purposes. Table 4-4 summarizes the laboratory analytical detection results for the upgradient samples.

4.6.1.1 Select Metals and PAHs in Soil – Trap Range

Select Metals and PAHs – Laboratory Analyses

All six XRF soil samples that exceeded the field lead screening level (100 mg/kg) for the Trap Range area were subsequently submitted to the FBL for select metals and PAH analysis. Below is a discussion of the select metals and PAH laboratory results for these samples.

Lead

Lead laboratory analytical soil sample concentrations ranged from 127 to 193 mg/kg. None of the surface soil samples submitted for laboratory analyses exhibited lead concentrations exceeding the human health PAL of 400 mg/kg (Figure 4-5 and Table 4-3). However, all six samples exhibited exceedances of the ecological PAL of 11 mg/kg for lead. In addition, all six samples showed concentrations, which exceeded the Illinois EPA soil background concentration for lead of 36 mg/kg.

Antimony

Antimony laboratory analytical concentrations ranged from 0.641 to 1.07 mg/kg. None of the surface soil samples submitted for laboratory analyses exhibited antimony concentrations exceeding the human health PAL of 31 mg/kg (Figure 4-5 and Table 4-3). However, all six samples exhibited exceedances of the ecological PAL of 0.27 mg/kg. In addition, all six samples showed concentrations less than the Illinois EPA background concentration for antimony of 4 mg/kg. A statistical comparison of the exposure point concentration, represented by the 95 percent upper confidence limit of the mean, to the Illinois EPA background soil concentrations for antimony indicates that the concentrations of antimony detected in the soil samples collected from the Trap Range area are within the range of naturally occurring antimony concentrations in the area of the site (Appendix G).

Arsenic

Arsenic laboratory analytical concentrations ranged from 8.51 to 10.7 mg/kg. All six of the surface soil samples submitted for laboratory analyses exhibited arsenic concentrations exceeding the residential human health PAL of 0.39 mg/kg (Figure 4-5 and Table 4-3). Additional screening of the arsenic concentrations against the TACO construction worker ingestion criteria of 61 mg/kg indicated no exceedances. However all detected concentrations exceed the USEPA industrial screening level of 1.6 mg/kg.

None of the six samples exhibited exceedances of the ecological PAL of 18 mg/kg. In addition, all six samples showed concentrations less than the Illinois EPA background concentration for arsenic of 13 mg/kg. A statistical comparison of the exposure point concentration, represented by the 95 percent upper confidence limit of the mean, to the Illinois EPA background soil concentrations for arsenic indicates that the concentrations of arsenic detected in the soil samples collected from the Trap Range area are within the range of naturally occurring antimony concentrations in the area of the site (Appendix G).

PAHs

Table 4-3 summarizes the analytical results and any exceedance as compared to the screening PALs for PAHs. In Table 4-3, if a parameter exceeded the PAL at any sampling point, the parameter was highlighted (human health PAL exceedance), bolded (ecological PAL exceedance), or highlighted and bolded if both PALs are exceeded.

Six surface soil samples were sent to the FBL for PAH analysis. Nine PAHs were detected in the surface soil samples collected from the Trap Range area of the TSA Ranges at concentrations in excess of a PAL screening criteria (either human health, ecological, or both). The PAHs detected in at least one of the samples include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)anthracene, and pyrene. Five of the six samples exhibited concentrations of several PAHs in excess of a PAL. The only sample which did not have concentrations of individual PAHs at elevated concentrations was TSA-060, located in the northern portion of the Trap Range area.

In addition, the benzo(a)pyrene (BaP) equivalent concentration exceeded the human health PAL in all six of the surface soil samples, ranging from 121 to 20,279 µg/kg. A description on how the BaP equivalent

concentration was derived is presented in Section 3.6. Table 4-3 presents the calculated BaP equivalent concentrations. The BaP equivalent residential human health PAL is 90 µg/kg. The ecological PAL is 1,100 µg/kg for individual high molecular weight PAHs, and 29,000 µg/kg for individual low molecular weight PAHs.

The PAHs are believed to be associated with the fragments of the clay pigeons used as targets on the trap range. A pitch tar containing PAHs was used in the manufacture of the clay pigeons to help bind the clay particles. Any observance of clay target remnants was noted in the sample log sheets (Appendix A). Appendix D includes the full analytical results for the PAHs analyzed.

4.6.1.2 Select Metals and PAHs in Sediment – Trap Range

Below is a discussion of the select metals and PAHs detected in the sediment samples collected from the TSA Ranges – Trap Range area submitted to the FBL for analyses:

Lead

Lead laboratory analytical sediment sample concentrations ranged from 16.6 to 23.5 mg/kg for the Trap Range area. None of the sediment samples submitted for laboratory analyses exhibited lead concentrations exceeding the ecological PAL of 35.8 mg/kg (Table 4-4).

Antimony

All six of the sediment samples collected from the Trap Range area exhibited antimony concentrations below the laboratory detection limit, which is less than the ecological PAL of 2 mg/kg (Table 4-4).

Arsenic

Arsenic laboratory analytical sediment sample concentrations ranged from 2.6 to 3.03 mg/kg in the Trap Range area. None of the sediment samples submitted for laboratory analyses exhibited arsenic concentrations exceeding the ecological PAL of 9.79 mg/kg (Table 4-4).

PAHs

None of the sediment samples collected for the Trap Range area exhibited concentrations of any PAHs above its respective ecological PAL (Table 4-4).

4.6.1.3 Select Metals and PAHs in Soil – Skeet Range

Select Metals – Laboratory Analyses

All 14 XRF samples that exceeded the field lead screening level for the Skeet Range area were subsequently submitted to the FBL for select metals and PAH analysis. Below is a discussion of the select metals and PAH laboratory results for these samples.

Lead

Lead laboratory analytical concentrations ranged from 152 to 1,460 mg/kg. Five of the surface soil samples submitted for laboratory analyses exhibited lead concentrations exceeding the human health PAL of 400 mg/kg (Figure 4-6 and Table 4-3). Two samples (TSA-23 and TSA-30) exceed the TACO construction worker screening value of 700 mg/kg (Appendix D, Table D-1). However, all 14 samples exhibited exceedances of the ecological PAL of 11 mg/kg for lead, and exceeded the Illinois EPA background concentration for lead of 36 mg/kg.

Antimony

Antimony laboratory analytical concentrations ranged from 0.734 to 3.68 mg/kg. None of the surface soil samples submitted for laboratory analyses exhibited antimony concentrations exceeding the human health PAL of 31 mg/kg (Figure 4-6 and Table 4-3). However, all 14 samples exhibited exceedances of the ecological PAL of 0.27 mg/kg. In addition, all 14 samples showed concentrations less than the Illinois EPA background concentration for antimony of 4 mg/kg. A statistical comparison of the exposure point concentration, represented by the 95 percent upper confidence limit of the mean, to the Illinois EPA background soil concentrations for antimony indicates that the concentrations of antimony detected in the soil samples collected from the Skeet Range area are within the range of naturally occurring antimony concentrations in the area of the site (Appendix G).

Arsenic

Arsenic laboratory analytical concentrations ranged from 5.58 to 19.6 mg/kg. All 14 of the surface soil samples submitted for laboratory analyses exhibited arsenic concentrations exceeding the human health PAL of 0.39 mg/kg (Figure 4-6 and Table 4-3). No surface soil samples exceed the TACO construction worker ingestion criteria of 61 mg/kg. However all detected concentrations exceed the USEPA industrial screening level of 1.6 mg/kg.

Only one sample (TSA-041) exhibited exceedances of the ecological PAL of 18 mg/kg. The same sample was the only one which showed a concentration above the Illinois EPA background concentration for arsenic of 13 mg/kg. However, a statistical comparison of the exposure point concentration, represented by the 95 percent upper confidence limit of the mean, to the Illinois EPA background soil concentrations for arsenic indicates that the concentrations of arsenic detected in the soil samples collected from the Skeet Range area are within the range of naturally occurring antimony concentrations in the area of the site (Appendix G).

PAHs

Table 4-3 summarizes the analytical results and any exceedance of the PALs for PAHs. In Table 4-3, if a parameter exceeded the PAL at any sampling point, the parameter was highlighted (human health PAL exceedance), bolded (ecological PAL exceedance), or highlighted and bolded if both PALs are exceeded.

Fourteen surface soil samples collected from the Skeet Range area were sent to the FBL for PAH analysis. Only benzo(a)pyrene, was detected in 12 of the 14 surface soil samples at concentrations in exceedance of the TACO PAL screening criteria of 90 µg/kg (human health only). The concentrations of benzo(a)pyrene also exceeded the TACO construction worker screening criteria of 17 µg/kg and the USEPA industrial criteria of 0.21 µg/kg. The only samples, which did not have concentrations of PAHs at elevated concentrations, were TSA-031 and TSA-044.

In addition, the BaP equivalent concentration exceeded the PAL in 12 of the surface soil samples. A description on how the BaP equivalent concentration was derived is presented in Section 3.6. Table 4-3 presents the calculated BaP equivalent concentrations. The BaP equivalent human health PAL is 90 µg/kg. The ecological PAL is 1,100 µg/kg for individual high molecular weight PAHs and 29,000 micrograms per kilogram (µg/kg) for individual low molecular weight PAHs.

The PAHs appear to be associated with the fragments of the clay pigeons used as targets on the trap range. A pitch tar containing PAHs was used in the manufacture of the clay pigeons to help bind the clay particles. Any observance of clay target remnants was noted in the sample log sheets. Appendix D includes the full analytical results for the PAHs analyzed.

4.6.1.4 Select Metals and PAHs in Sediment – Skeet Range

Below is a discussion of the select metals and PAHs detected in the sediment samples collected from the Skeet Range area submitted to the FBL for analyses:

Lead

Lead laboratory analytical concentrations for the sediment samples collected from the Skeet Range area ranged from 15.7 to 204 mg/kg (Figure 4-9 and Table 4-4). Five of the sediment samples submitted for laboratory analyses exhibited lead concentrations exceeding the ecological PAL of 35.8 mg/kg for lead. In addition, a statistical comparison of the TSA Ranges sediment data to the upgradient/background sediment sample concentrations for lead indicates that the concentrations of lead detected in the sediment samples collected from the Skeet Range area are above the upgradient/background concentrations for lead (Appendix G).

The ecological screening level is based on the threshold effects concentration (TEC) from MacDonald et al. (2000), which is the concentration below which effects to sediment invertebrates are not expected. The probable effects concentration (PEC) from MacDonald et al. (2000) for lead is 128 mg/kg, which is the concentration above which effects to sediment invertebrates are likely to be observed. Only one location (TSA-078) had a lead concentration that exceeded the PEC. This location was well bounded by samples with lead concentrations either just slightly greater than or less than the screening level (see Figure 4-9). The locations with lead concentrations between the TEC and the PEC, which represents an area of uncertainty with regards to toxic effects to sediment invertebrates, are bounded to a small area along the shoreline. Therefore, although it is possible that lead is impacting sediment invertebrates, any impacts are limited to a small area.

Antimony

None of the sediment samples submitted for laboratory analyses exhibited antimony concentrations exceeding the ecological PAL of 3 mg/kg (Table 4-4).

Arsenic

None of the sediment samples submitted for laboratory analyses exhibited arsenic concentrations exceeding the ecological PAL of 9.79 mg/kg (Table 4-4).

PAHs

None of the sediment samples collected for the Skeet Range area exhibited concentrations of any PAHs above its respective ecological PAL.

4.7 UPDATED CSM

Table 4-5 contains the tabular CSM, which outlines the current understanding of the TSA Ranges. Figure 4-11 provides a graphical representation of the current understanding of the TSA Ranges. The figures identify the exposure pathways where site receptors could be exposed to in contact with, or be impacted by, MC. Based on the analytical information obtained during the SI, MC does exist at the TSA Ranges.

4.8 CONCLUSIONS

The initial environmental data collected during the SI sampling activities are sufficient to determine the presence of MC (lead and PAHs) associated with the former use of the ranges in the surface soils, and to provide preliminary horizontal (north to south) delineation of impacted surface soils. The extent of MC to the west and vertically in the subsurface soil has not been determined for the site. Identification of clay pigeon fragments and shotgun shell wadding in surface soils and along the erosional face of the former Trap Range indicates that a continuing source of PAHs may be present in the soil. Grading of the site for use as an RV park may have covered soil that contains MC located closer to the former firing line.

The focused SI sampling activities characterized the local site conditions in surface soils (0 to 0.5 feet bgs) and sediment (0 to 0.5 feet bss) and identified concentrations of MC associated with small arms ammunition in surface soil and sediment. MCs (lead and PAHs) were identified at concentrations above PALs in the surface soil of the TSA Ranges. MC in soil may bioaccumulate in plants or animals and then be consumed by animals foraging on the former ranges. Predation of prey and/or consumption of vegetation on the range may result in bioaccumulation of MC. Complete exposure pathways are identified for biota that may be exposed to MC through the food chain. In addition, potential human receptors (i.e., Navy personnel, visitors, and construction workers) may be exposed to MC through direct contact (ingestion, inhalation of particulates) with the impacted soils or less likely, consumption of biota.

MCs (antimony and lead) in the sediment samples collected from the TSA Ranges exhibited concentrations above both ecological PALs and the site-specific upgradient/background sediment sample data. Complete exposure pathways are identified for aquatic biota that may be exposed to MC through

direct contact with the sediment and via the food chain. In addition, to a lesser extent, potential human receptors (i.e., fisherman) may come in contact with MC through consumption of aquatic biota.

4.9 RECOMMENDATIONS

The purpose of the SI phase of this project is to identify possible contaminant releases that require further investigation or pose a threat to human health and/or the environment.

SOIL

The SI identified a limited area in the TSA Ranges with lead, and PAH concentrations greater than respective PALs and the Illinois EPA background soil concentrations in surface soil within the project site. Based on the SI findings, further actions are required.

Additional focused sampling (horizontally and vertically) is recommended at the TSA Ranges to further characterize and quantify the contaminated range soil areas and identify discrete areas where removal actions could address the MC-contaminated soils that pose a threat to human health or the environment.

SEDIMENT

The SI identified a limited area of sediment near shore within the TSA Ranges with lead concentrations greater than their respective ecological PALs and the site-specific upgradient/background sediment sample data. However, lead concentrations only exceeded the PEC in one well bounded location, surrounded by sample locations with concentrations below or nominally above the screening criteria. Therefore, the potentially impacted area is relatively small and impact to aquatic biota appears to be insignificant; therefore, further evaluation of ecological risks is warranted, and recommended.

TABLE 4-4

SUMMARY OF DETECTED CONCENTRATIONS IN SEDIMENT
TSA RANGES
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

LOCATION SAMPLE ID SAMPLE DATE DEPTH (ft bss)	Federal Ecological Screening Criteria (Region 5 SSLs) [1]	NTC-SD-TSA-061 NTC-SD-TSA-061-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-062 NTC-SD-TSA-062-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-063 NTC-SD-TSA-063-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-064 NTC-SD-TSA-064-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-065 NTC-SD-TSA-065-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-066 NTC-SD-TSA-066-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-067 NTC-SD-TSA-067-0006 05/19/2010 0 - 0.5
METALS (mg/kg)								
Antimony	2	0.301 U	0.319 U	0.295 U	0.309 U	0.321 U	0.308 U	0.306 U
Arsenic	9.79	2.77 J	2.95 J	3.03 J	2.72 J	2.78 J	2.6 J	2.58 J
Copper	31.6	NA	NA	NA	NA	NA	NA	NA
Iron	20000	NA	NA	NA	NA	NA	NA	NA
Lead	35.8	20	23.5	18.5	17.5	16.6	16.8	18.7
Magnesium	NC	NA	NA	NA	NA	NA	NA	NA
Strontium	NC	NA	NA	NA	NA	NA	NA	NA
Zinc	121	NA	NA	NA	NA	NA	NA	NA
POLYCYCLIC AROMATIC HYDROCARBONS (µg/kg)								
1-Methylnaphthalene	20.2	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
2-Methylnaphthalene	20.2	2.31 J	1.66 U	1.63 U	1.68 U	2.06 J	1.67 U	1.68 U
Acenaphthene	6.71	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Anthracene	57.2	17	1.66 U	1.63 U	17.4	1.68 U	1.67 U	17.9
BaP Equivalent	150	3.304075	1.66 U	3.141965	1.68 U	1.68 U	1.67 U	1.68 U
Benzo(a)anthracene	108	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Benzo(a)pyrene	150	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Benzo(b)fluoranthene	10400	14.8	1.66 U	13.4	1.68 U	1.68 U	1.67 U	1.68 U
Benzo(g,h,i)perylene	170	1.65 UJ	1.66 UJ	1.63 UJ	1.68 UJ	1.68 UJ	1.67 UJ	1.68 UJ
Benzo(k)fluoranthene	240	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Chrysene	166	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Fluoranthene	423	11.9	8.24 J	8.24	10.6	15.3	13.1	10.4
Fluorene	77.4	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Indeno(1,2,3-cd)pyrene	200	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Naphthalene	176	1.65 U	1.66 U	1.63 U	1.68 U	1.68 U	1.67 U	1.68 U
Phenanthrene	204	7.73 J	5.19 J	4.38 J	8.2 J	1.68 U	9.29	6.57 J
Pyrene	195	28	25.7	25.3	27.8	30.7	29.4	27.4

LOCATION SAMPLE ID SAMPLE DATE DEPTH (ft bss)	Federal Ecological Screening Criteria (Region 5 SSLs) [1]	NTC-SD-TSA-068 NTC-SD-TSA-068-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-069 NTC-SD-TSA-069-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-070 NTC-SD-TSA-070-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-071 NTC-SD-TSA-071-0006 05/19/2010 0 - 0.5	NTC-SD-TSA-072 NTC-SD-TSA-072-0006 05/23/2010 0 - 0.5	NTC-SD-TSA-073 NTC-SD-TSA-073-0006 05/23/2010 0 - 0.5	NTC-SD-TSA-074 NTC-SD-TSA-074-0006 05/23/2010 0 - 0.5
METALS (mg/kg)								
Antimony	3	0.324 U	0.313 U	0.312 U	0.32 U	0.328 J	2.4 J	0.289 U
Arsenic	9.79	3.19 J	2.87 J	3.35 J	2.82 J	2.91	2.7	3.02
Copper	31.6	NA	NA	NA	NA	NA	NA	NA
Iron	20000	NA	NA	NA	NA	NA	NA	NA
Lead	35.8	17.3	18.8	25.3	17.6	**109 J**	**48.1 J**	**44.4 J**
Magnesium	NC	NA	NA	NA	NA	NA	NA	NA
Strontium	NC	NA	NA	NA	NA	NA	NA	NA
Zinc	121	NA	NA	NA	NA	NA	NA	NA
POLYCYCLIC AROMATIC HYDROCARBONS (µg/kg)								
1-Methylnaphthalene	20.2	1.7 U	1.67 U	2.06 J	1.96 J	1.93 J	1.6 U	1.74 J
2-Methylnaphthalene	20.2	1.7 U	1.67 U	2 J	3.04 J	2.41 J	1.6 U	2.13 J
Acenaphthene	6.71	1.7 U	1.67 U	1.66 U	1.66 U	1.61 U	1.6 U	1.94 J
Anthracene	57.2	1.7 U	1.67 U	18	1.66 U	1.61 U	6.29 J	7.44 J
BaP Equivalent	150	1.7 U	1.67 U	24.095	1.66 U	20.29942	18.74214	3.2388
Benzo(a)anthracene	108	1.7 U	1.67 U	58.3	1.66 U	16.6	16.1	1.6 U
Benzo(a)pyrene	150	1.7 U	1.67 U	15.7	1.66 U	16.1	13.5	1.6 UJ
Benzo(b)fluoranthene	10400	1.7 U	1.67 U	16.3	1.66 U	16.4	1.6 U	14.7
Benzo(g,h,i)perylene	170	1.7 UJ	1.67 UJ	1.66 UJ	1.66 UJ	3.8 J	2.45 J	1.93 J
Benzo(k)fluoranthene	240	1.7 U	1.67 U	1.66 U	1.66 U	1.61 U	1.6 U	1.6 U
Chrysene	166	1.7 U	1.67 U	13.7	1.66 U	5.87 J	4.14 J	1.6 U
Fluoranthene	423	10.1	8.05 J	16.2	9.31	13.4	1.6 U	1.6 U
Fluorene	77.4	1.7 U	1.67 U	2.16 J	1.66 U	3.41 J	1.6 U	1.6 U
Indeno(1,2,3-cd)pyrene	200	1.7 U	1.67 U	1.66 U	1.66 U	1.61 U	27.4	1.6 U
Naphthalene	176	1.7 U	1.67 U	1.66 U	1.66 U	1.61 U	1.6 U	1.6 U
Phenanthrene	204	6.25 J	4.65 J	11.5	6.93 J	15.2	8.1	10.6
Pyrene	195	27.8	25.2	31.2	27.5	12.1	9.02	9.63

Footnotes and definitions are summarized on the final page of the table.

TABLE 4-4

SUMMARY OF DETECTED CONCENTRATIONS IN SEDIMENT
TSA RANGES
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

LOCATION SAMPLE ID SAMPLE DATE DEPTH (ft bss)	Federal Ecological Screening Criteria (Region 5 SSLs) [1]	NTC-SD-TSA-075 NTC-SD-TSA-075-0006 05/23/2010 0 - 0.5	NTC-SD-TSA-076 NTC-SD-TSA-076-0006 05/23/2010 0 - 0.5	NTC-SD-TSA-077 NTC-SD-TSA-077-0006 05/23/2010 0 - 0.5	NTC-SD-TSA-078 NTC-SD-TSA-078-0006 05/23/2010 0 - 0.5	NTC-SD-UPG-001* NTC-SD-UPG-001-0006 05/19/2010 0 - 0.5	NTC-SD-UPG-002* NTC-SD-UPG-002-0006 05/19/2010 0 - 0.5	NTC-SD-UPG-003* NTC-SD-UPG-003-0006 05/19/2010 0 - 0.5
METALS (mg/kg)								
Antimony	2	0.313 U	0.302 U	0.311 U	1.06 J	0.337 U	0.312 U	0.304 U
Arsenic	9.79	2.26	2.29	2.64	2.89	2.67	3.14	3.17
Copper	31.6	NA	NA	NA	NA	3.52	4.53	4.05
Iron	20000	NA	NA	NA	NA	4100	4090	4560
Lead	35.8	20.3 J	18.2	**36**	**204**	16.8	16.3	8.98
Magnesium	NC	NA	NA	NA	NA	31500 J	34900	27800 J
Strontium	NC	NA	NA	NA	NA	24.6	27.3	27.7
Zinc	121	NA	NA	NA	NA	36.2	30.4	27.3
POLYCYCLIC AROMATIC HYDROCARBONS (µg/kg)								
1-Methylnaphthalene	20.2	1.71 U	1.66 U	4.73 J	2.41 J	1.75 UR	1.74 UR	5.07 J
2-Methylnaphthalene	20.2	1.71 U	1.66 U	9.54	2.26 J	1.75 UR	1.74 UR	6.25 J
Acenaphthene	6.71	1.71 U	1.66 U	1.65 U	1.61 U	1.75 UR	1.74 UR	1.69 UR
Anthracene	57.2	1.71 U	1.66 U	6.58 J	6.38 J	3.46 J	1.74 UR	1.69 UR
BaP Equivalent	150	3.230405	19.30729	4.94976	3.109855	1.75 UR	6.72052	19.08
Benzo(a)anthracene	108	1.71 U	17.6	16.1	1.61 U	1.75 UR	4.22 J	12.2 J
Benzo(a)pyrene	150	1.71 U	15	1.65 U	1.61 U	1.75 UR	1.74 UR	12.2 J
Benzo(b)fluoranthene	10400	13.4	16.2	15.7	13.3	1.75 UR	26.2 J	37.6 J
Benzo(g,h,i)perylene	170	1.71 U	3.08 J	1.65 U	1.61 U	1.75 UR	1.74 UR	11.6 J
Benzo(k)fluoranthene	240	1.71 U	1.66 U	3.36 J	1.61 U	1.75 UR	1.74 UR	1.69 UR
Chrysene	166	1.71 U	5.99 J	3.66 J	1.61 U	1.75 UR	7.12 J	24.1 J
Fluoranthene	423	1.71 U	1.66 U	1.65 U	1.61 U	10.4 J	15.2 J	58.8 J
Fluorene	77.4	1.82 J	3.09 J	1.76 J	1.61 U	2.29 J	2.92 J	1.69 UR
Indeno(1,2,3-cd)pyrene	200	1.71 U	1.66 U	1.65 U	1.61 U	1.75 UR	1.74 UR	1.69 UR
Naphthalene	176	1.71 U	1.66 U	9.08	1.61 U	1.75 UR	1.74 UR	1.69 UR
Phenanthrene	204	5.37 J	10.4	6.8 J	5.13 J	8.72 J	10.3 J	40.3 J
Pyrene	195	6.52 J	11.9	8.38	6.11 J	8.91 J	11.2 J	43.7 J

LOCATION SAMPLE ID SAMPLE DATE DEPTH (ft bss)	Federal Ecological Screening Criteria (Region 5 SSLs) [1]	NTC-SD-UPG-004* NTC-SD-UPG-004-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-005* NTC-SD-UPG-005-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-006* NTC-SD-UPG-006-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-007* NTC-SD-UPG-007-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-008* NTC-SD-UPG-008-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-009* NTC-SD-UPG-009-0006 05/20/2010 0 - 0.5	NTC-SD-UPG-010* NTC-SD-UPG-010-0006 05/20/2010 0 - 0.5
METALS (mg/kg)								
Antimony	3	0.309 U	0.306 U	0.298 U	0.326 U	0.345 U	0.293 UJ	0.308 U
Arsenic	9.79	3.89	9.56	5.22	3.04	4.26	6.42	**10.7**
Copper	31.6	2.53	15.2	4.44	5.5	3.53	2.08	6.66
Iron	20000	3610	14900	5800	4620	4560	5260	6630
Lead	35.8	4.05	9.01	7.31	11.5	11.1	5.05	27.3
Magnesium	NC	9860 J	36300	22500 J	32000 J	14600 J	15100 J	12700 J
Strontium	NC	12.1	40.6	25	25.1	15.5	11.4	12.4
Zinc	121	15.7	34.8	26.1	27.9	24.3	14.2 J	44.9
POLYCYCLIC AROMATIC HYDROCARBONS (µg/kg)								
1-Methylnaphthalene	20.2	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	20.2	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	6.71	NA	NA	NA	NA	NA	NA	NA
Anthracene	57.2	NA	NA	NA	NA	NA	NA	NA
BaP Equivalent	150	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	108	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	150	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	10400	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	170	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	240	NA	NA	NA	NA	NA	NA	NA
Chrysene	166	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	423	NA	NA	NA	NA	NA	NA	NA
Fluorene	77.4	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	200	NA	NA	NA	NA	NA	NA	NA
Naphthalene	176	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	204	NA	NA	NA	NA	NA	NA	NA
Pyrene	195	NA	NA	NA	NA	NA	NA	NA

Footnotes and definitions are summarized on the final page of the table.

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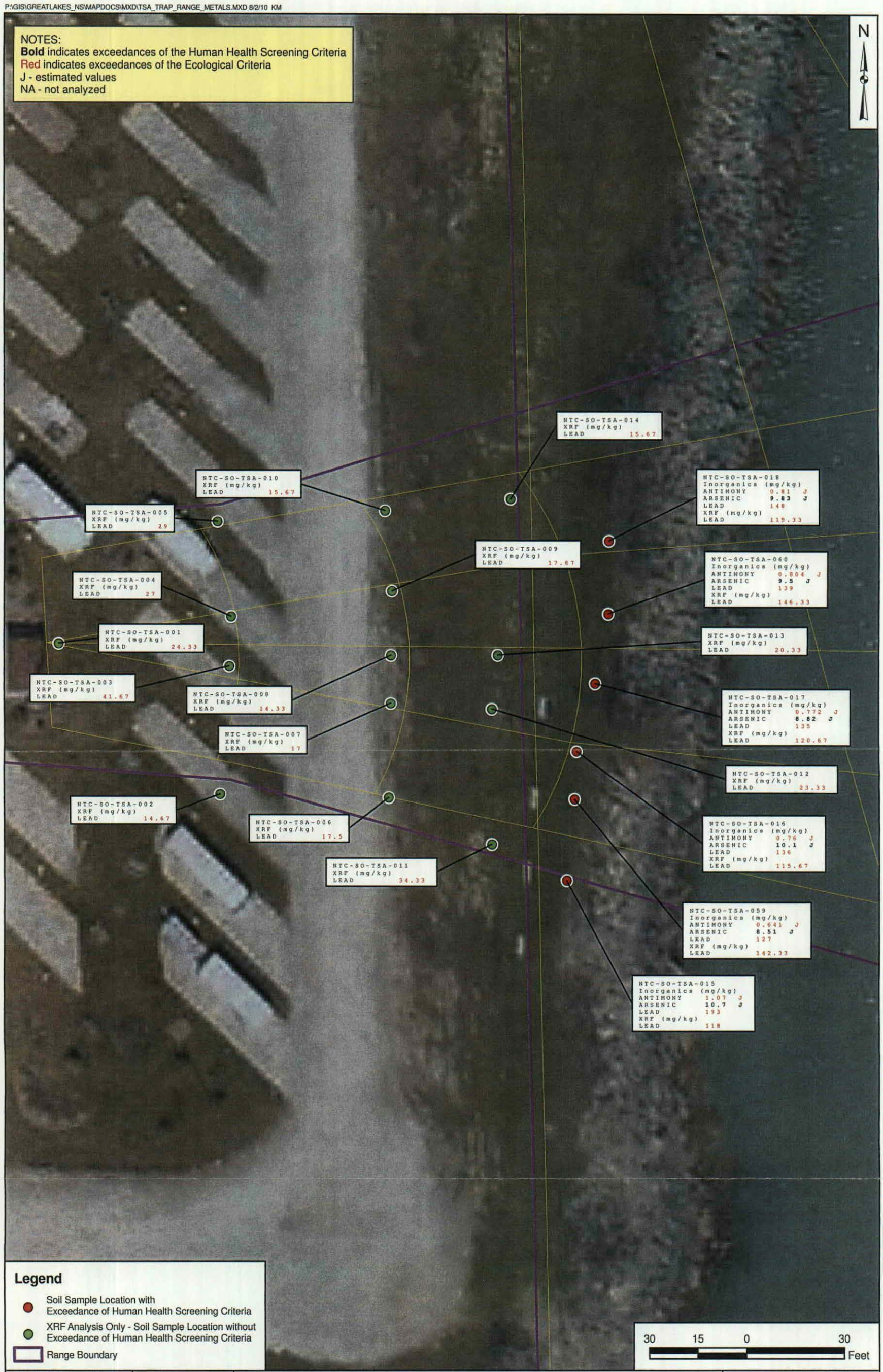

DRAWN BY	DATE
K. MOORE	7/21/10
CHECKED BY	DATE
J. DUCAR	8/2/10
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

SELECT METALS AND XRF DETECTIONS IN SOIL
TSA RANGES - TRAP RANGE
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	
CTO F274	
OWNER NUMBER	
—	
APPROVED BY	DATE
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FIGURE NO.	REV
FIGURE 4-5	0

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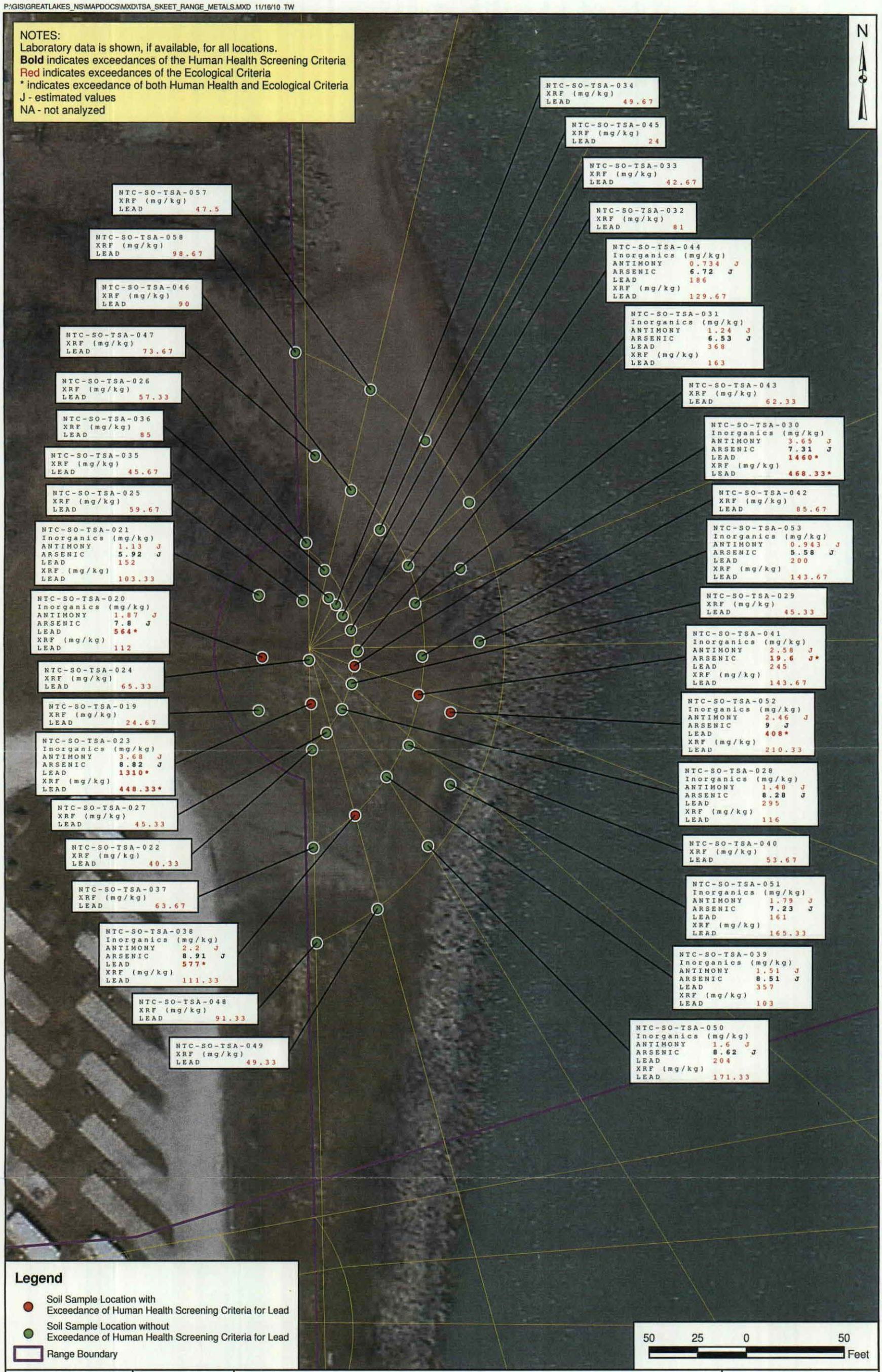

DRAWN BY	DATE
K. MOORE	07/21/10
CHECKED BY	DATE
J. DUCAR	11/16/10
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

SELECT METALS AND XRF DETECTIONS IN SOIL
TSA RANGES - SKEET RANGE
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	
CTO F274	
OWNER NUMBER	
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APPROVED BY	DATE
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FIGURE NO.	REV
FIGURE 4-6	0

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DRAWN BY	DATE
K. MOORE	7/29/10
CHECKED BY	DATE
J. DUCAR	8/4/10
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

PAH EXCEEDANCES IN SOIL
TSA RANGES - TRAP RANGE
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	
CTO F274	
OWNER NUMBER	
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APPROVED BY	DATE
—	—
FIGURE NO.	REV
FIGURE 4-7	0

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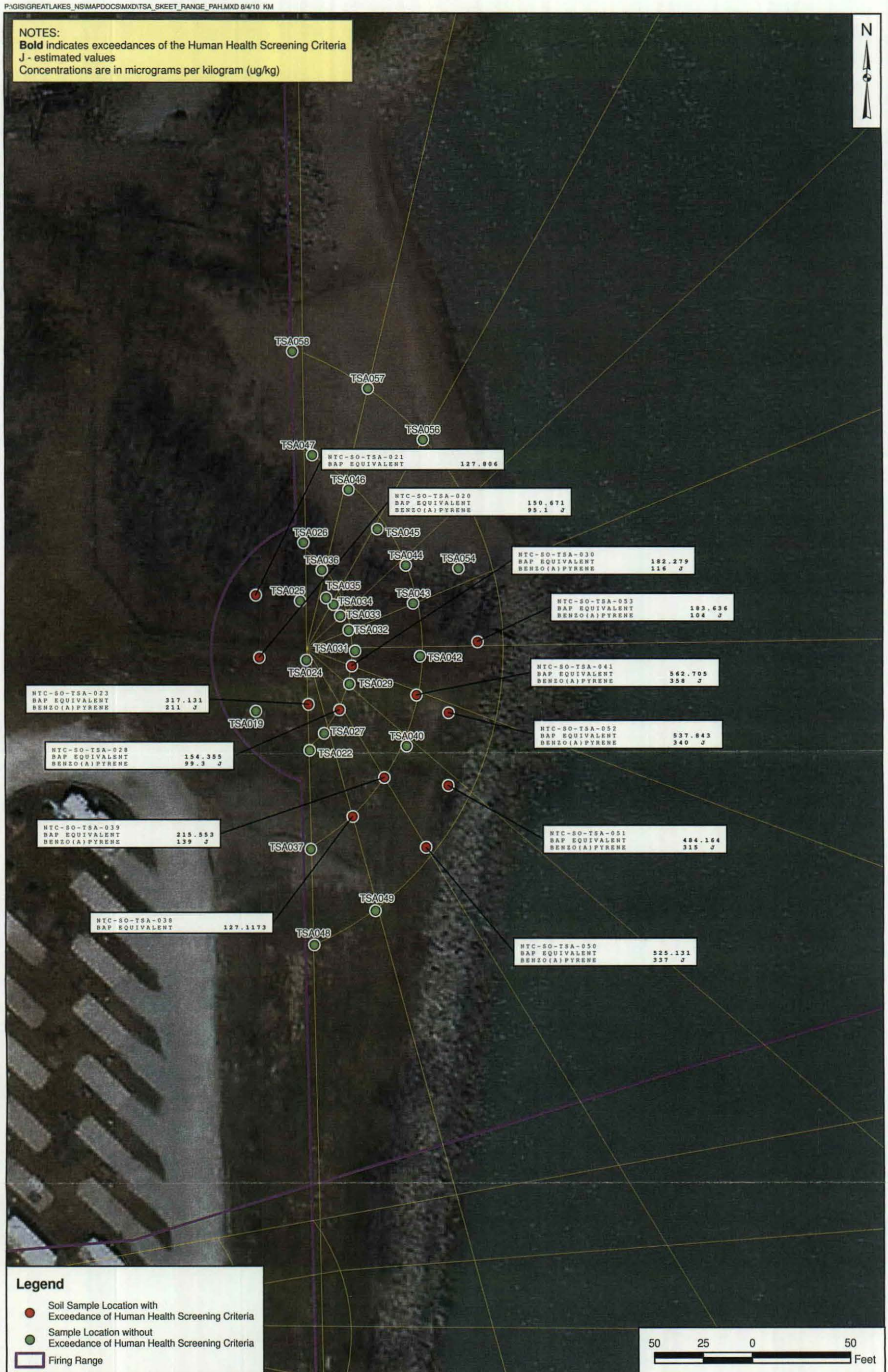

DRAWN BY	DATE
K. MOORE	7/29/10
CHECKED BY	DATE
J. DUCAR	8/4/10
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

PAH EXCEEDANCES IN SOIL
TSA RANGES - SKEET RANGE
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	
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FIGURE NO.	REV
FIGURE 4-8	0

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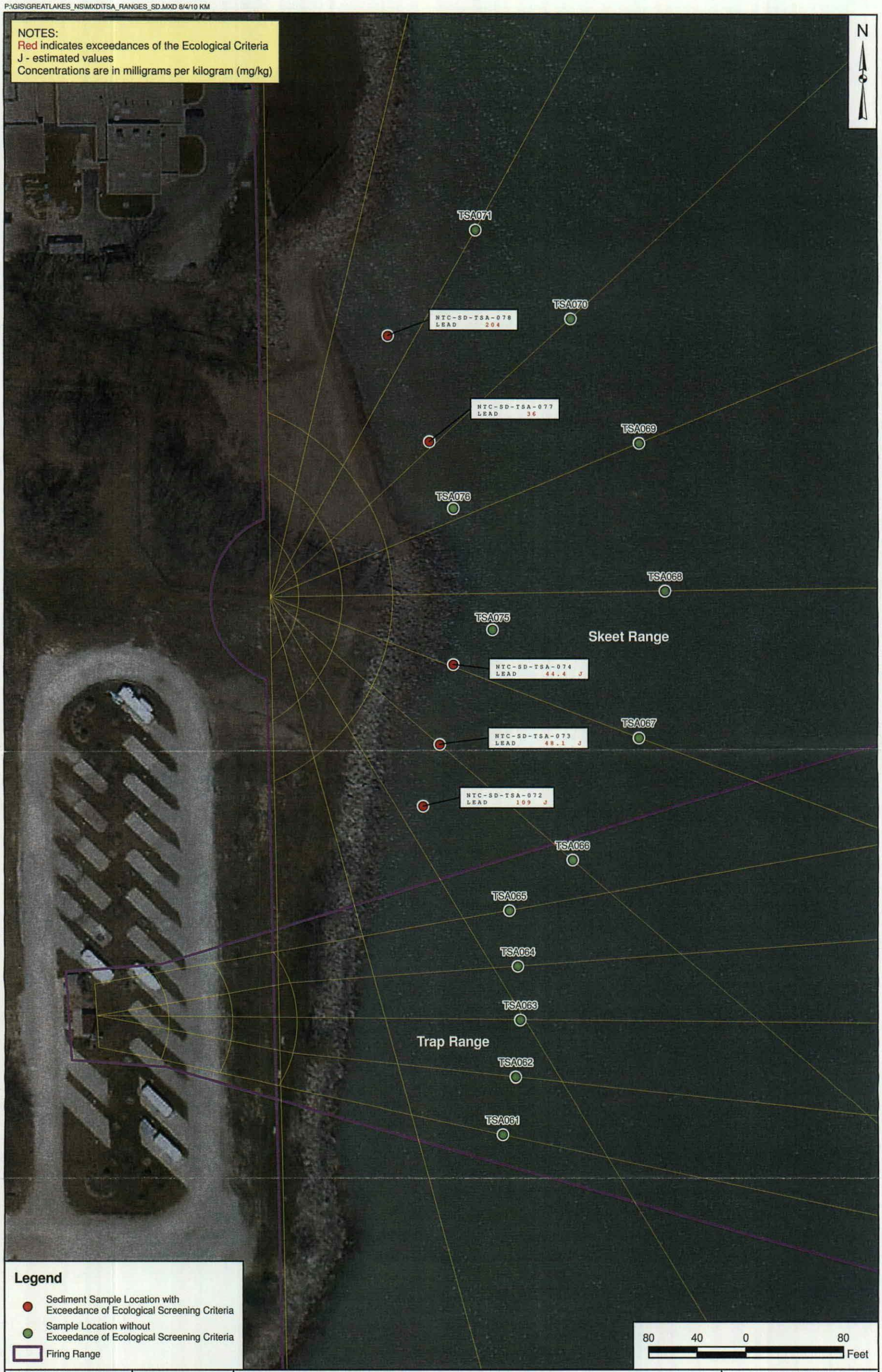

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K. MOORE	7/29/10
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J. DUCAR	8/4/10
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NAVFAC

SELECT METALS EXCEEDANCES IN SEDIMENT
TSA RANGES
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	
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FIGURE NO.	REV
FIGURE 4-9	0

7.0 NTC LAKEFRONT

7.1 SITE BACKGROUND

Between 1942 and 1945, personnel stationed at NSGL used the NTC Lakefront for AA artillery training. At that time, 25 gun mounts located on the beachfront were used to fire at targets towed over Lake Michigan. The SI field investigation was conducted on the water portion, which includes the range fan and SDZ over Lake Michigan, which is where a fired munition would have landed. Information regarding NTC Lakefront is limited to the history and site description presented in the Final Water Area Munitions Study NTC Lakefront (Malcolm Pirnie, 2005) and the PA (Malcolm Pirnie, 2008).

The land portion of NTC Lakefront is approximately one acre in size and is located east of the bluff on the beachfront of Lake Michigan. Prior to using the site as an AA range, the shoreline was extended with fill material in order to install the machine gun mounts. The water portion of this site includes a fan area of approximately 4,765 acres that extends out from the shoreline over Lake Michigan.

The NTC Lakefront is bordered by Lake Michigan to the east, a RV park to the north, the bluff to the west, and the Outer Harbor and Boat House to the south. The site is accessible via Ziegemeir Street, which is built over the former gun mount roundels. A magazine, Building 120, is the present lakefront magazine according to a March 17, 2003 listing of known ammunition storage and firing locations at NSGL. Over the years, the buildings associated with the Site, including the Garage and Storage, the Machine Gun Training Building, the Armory, and the Clippings and Empties building, were demolished. Sometime after 1962, a tank farm for fuel storage was constructed in the location of the former Machine Gun Training Building to meet the needs of the power plant. No construction records for the tank farm were available that could provide information regarding potential munitions findings and no visible signs of the demolished buildings exist today. The power plant is adjacent to the tank farm that services it (former location of the NTC Lakefront).

Figure 7-1 depicts NTC Lakefront and associated range features.

7.1.1 Historical Munitions Usage Information

Approximately 1,350 sailors a day were instructed in AA training using 20- and 40-millimeter guns and shot several million shells at cable-drawn targets towed by airplanes over Lake Michigan. Potential MEC and/or MPPEH issues arose from the use of AA ammunition with tracers including:

- 20-mm HE
- HEI
- HET
- HET-DI rounds
- 40-mm blind loaded and plugged (BL&P)
- HET – self destruct (HET-SD)
- high explosive incendiary tracer – self destruct (HEIT-SD) rounds
- 1.1-inch AA artillery
- 3-inch .50 caliber artillery
- DI tracers

Based on the information obtained during the data collection process, no special consideration munitions are known or suspected to have been used at the site. Therefore, NTC Lakefront is not suspected to contain chemical warfare material filled munitions, electrically fuzed munitions, or depleted uranium associated munitions (Malcolm Pirnie, 2005). Additional technical data regarding the munitions used at NTC Lakefront are included in Appendix A-3 of the UFP-SAP.

It is estimated that more than ten million rounds of ammunition were fired between 1942 and 1945. The dud rate is estimated at 5 percent, resulting in potentially several hundred thousand rounds containing explosives, which may be present in the Lake Michigan sediment. Munitions that missed the target could have auto-detonated 3,000 yards from the firing point, which indicates that MEC/MPPEH or MEC debris may be present at this distance from the firing point within Lake Michigan. Munitions that did not detonate at this distance may have traveled a considerable distance before impact, depending on the munition type and typical range. Some of the munitions fired had potential ranges of more than 30,000 feet (5.68 miles).

7.1.2 Munitions Constituents

MC could be present in lake sediment associated with the remaining MEC/MPPEH in the SDZ, primarily in the primary impact zone. However, the concentrations of MC in Lake Michigan surface water resulting from the use of munitions at the range would likely become extremely diluted by the large volume of surface water and the length of time since the placement of the MC occurred. The MC potentially present NTC Lakefront includes:

- Select metals: antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc; and

- Select explosives: octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), pentaerythritol tetranitrate (PETN), n-methyl-n-2,4,6-tetranitroaniline (tetryl), and trinitrotoluene (TNT).

7.2 SITE FIELDWORK

7.2.1 Site Field Activities

MEC Investigation

Data and information used to make environmental management decisions about Lake Michigan for the MEC investigation include the following:

1. Control Point Data: Site preparation consisted of locating or establishing an adequate number of control points to provide accurate navigational control for the survey work.

2. Bathymetric Survey Data: Technicians used high-resolution multibeam echosounder sonar (MBE) system capable of detecting and identifying features such as potential MEC/MPPEH on the surface of lake sediment. The bathymetric survey was used to map the lake bottom and morphology in addition to identifying obstacles and features that may affect the in-water geophysical survey and any MEC removal activities. The bathymetric survey was conducted in general accordance with SOP 01 of the UFP-SAP; USACE's Hydrographic Surveying Engineering Manual (EM 1110-2-1003 and appendices; USACE, 2002) for an acoustic multi-beam survey as modified by the project-specific technical specifications provided in this work plan.

3. In-Water Geophysical Survey Data: Following the bathymetric survey the study transects were mapped using an underwater marine gradiometer array (MGA) to determine the density and distribution of metallic items that may represent suspect MEC, MPPEH, or scrap metal. All geophysical survey data was recorded electronically and field notes were recorded in field logbooks and/or survey log sheets. Any anomalies detected during the geophysical survey were used to determine whether any suspect MEC/MPPEH may be present on the lake bottom surface or subsurface. These data and their locations were also used to generate MC sampling locations.

4. Real Time Kinematic (RTK) GPS and ultra short acoustic baseline positioning system (USBL): The Leica 1230 RTK GPS/Applanix POS M/V and USBL systems were used to record watercraft and MGA position, dynamics and elevation data.

The horizontal boundary for the MEC SI at the NTC Lakefront is shown as the Lake Michigan SDZ as presented in Figure 7-1. This is the maximum depth covered by the Navy MRP. The vertical boundary (i.e., depth of sediment) of the MEC/MPPEH SI investigation of the lake bottom sediment is limited by the size of the anomalies present and the capabilities of the detection system. Small items (20-mm projectiles) may not be detected unless clustered together. Larger items such as 40-mm projectiles may be detected at depths up to approximately 12 inches in the bottom sediment depending on the technology used.

The data and results of analyses for the MEC/MPPEH geophysical investigation at NTC Lakefront suggest the following conclusions:

- The firing limits for the range (the north and south boundaries of the SDZ) have not been fully defined. The bands of metallic debris detected extend beyond the current estimated north and south boundaries of the historical AA training range.

- The terminus of the SDZ (eastern boundary) appears to be relatively well defined. The survey was completed to the design limits of the area (estimated maximum range of munitions). Even though the survey area ended about 915 feet short of the estimated maximum water depth range boundary based upon the depth limits set for the SI (i.e. water depth < 120 feet), the amount of metallic debris had tapered off significantly indicating that the terminal end of the range was in proximity to the end of the survey area

- Magnetic anomalies, which may represent MEC/MPPEH and/or MD were detected on the lake floor occurred in bands roughly corresponding to the different average ranges of the various known munitions fired at the range.

- The underwater video camera did not prove to be an effective tool for target/anomaly verification, although it did provide data about the lake bottom type and habitat.

Based on these considerations, additional evaluation will be needed to establish the nature and extent of potential MEC/MPPEH/MD contamination of the former AA training range at NSGL. The following activities may be warranted:

Diving operations to evaluate the nature of selected metallic items identified during the MGA survey.

Additional marine survey and geophysical mapping of areas to the north, south and east of the current survey area to bound (if possible) the metallic debris field (and potential UXO) associated with former range operations.

Volume II of the SI Report presents the MEC geophysical investigation report.

MC Investigation

The MC field investigation program for NTC Lakefront included collection of sediment samples from the area of the site within Lake Michigan to identify COPCs (e.g., select metals and select explosives) that may exist as a result of past operations at the range. Photographs associated with the sampling activities at NTC Lakefront are included in Appendix B.

No surface soil samples were collected at the firing line for the AA training area for NTC Lakefront due to the high erosion and deposition rates immediately in front of the firing points at that location. No MC is expected to remain near the firing lines.

Twenty-seven discrete sediment samples were collected from 30 sample locations identified through the NTC Lakefront MEC geophysical investigation with the use of a modified pneumatic Van Veen dredge sampler from the survey vessel, in accordance with SOP-08 of the UFP-SAP. Sediment samples could not be collected from three sample locations (LAK-012, LAK-014, and LAK-022) due to dredge sampler refusal. Sample locations were based on geophysical anomalies identified within the SDZ using a custom-designed MGA to perform the underwater geophysical survey.

All 27 sediment samples collected were submitted to the FBL for analysis of select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) by Method SW-846 6010B and select explosives (HMX, PETN, RDX, tetryl, and TNT) analyses by Method SW-846 8330A. All samples submitted to the laboratory were prepared and analyzed according to the normal laboratory protocol as identified on Worksheet #30 of the UFP-SAP.

Figure 7-2 presents the sediment sample locations within the assumed SDZ area of NTC Lakefront.

7.2.2 Work Plan Deviations

The only deviation from the UFP-SAP (Tetra Tech, 2010) for NTC Lakefront SI was that sediment samples could not be collected from three proposed sample locations (LAK-012, LAK-014, and LAK-022)

due to Van Veen dredge sampler refusal on the rocky lake bottom. Several attempts were made at each sample location, but samples could not be collected due to cobble size glacial sediments.

7.2.3 Field Data Collection

Twenty-seven discrete sediment samples were collected from 27 sample locations identified through the NTC Lakefront MEC geophysical investigation with the use of a modified Van Veen dredge sampler from the survey vessel, in accordance with SOP-08 of the UFP-SAP. Sample locations were based on geophysical anomalies identified within the SDZ by the MGA geophysical instrumentation.

All 27 sediment samples were submitted to the FBL for select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) analyses by Method SW-846 6010B and select explosives (HMX, PETN, RDX, tetryl, and TNT) analyses by Method SW-846 8330A. All samples submitted to the laboratory were prepared and analyzed according to the normal laboratory protocol as identified on Worksheet #30 of the UFP-SAP.

Table 7-1 provides a summary of the samples collected and their respective analysis at NTC Lakefront, and Figure 7-2 shows the sediment sampling and upgradient sediment sampling locations. Sediment sample log sheets are included in Appendix A.

Upgradient Sampling Locations

Three discrete sediment locations (LAK-UPG001 through LAK-UPG003) were collected at sample locations upgradient (north) of the TSA Range and seven discrete sediment samples (LAK-UPG004 through LAK-UPG010) were collected at sample locations upgradient (north) of the SDZ of NTC Lakefront. The sample locations were selected to be upgradient of the locations of magnetic anomalies identified during the MEC investigation and based on the general direction of the sediment transport along the coastal area as well as the suspected northern boundary of the SDZ.

All 10 sediment samples were submitted to the laboratory for select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) analyses by Method SW-846 6010B and three samples (LAK-UPG001 through LAK-UPG003) for PAHs analyses by Method 8270C. All the upgradient sediment samples were collected in accordance with SOP 08 of the UFP-SAP.

7.3 SITE INSPECTION DATA COLLECTION RESULTS

7.3.1 Munitions Constituents Sampling Results

Sediment samples collected at NTC Lakefront were compared to respective Ecological PALs, as listed in Worksheet #15 of the UFP-SAP (Tetra Tech, 2010). The data validation reports are presented in Appendix D.

Table 7-2 presents the select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) and select explosives (HMX, PETN, RDX, tetryl, and TNT) detections in the sediment samples at NTC Lakefront. The data comparison to PALs is discussed in Section 7.5.

Figure 7-3 presents the select metals (arsenic) and select explosives (HMX and RDX) detections in the sediment samples at NTC Lakefront.

7.4 DATA PRESENTATION/DATA USABILITY

7.4.1 Data Quality Review of Samples at NTC Lakefront

This section contains a description of the data review processes used to determine whether analytical laboratory data collected during the sampling field effort for NTC Lakefront were of acceptable quality for use in decision-making. The review began with data validation, which is a comparison of DQIs against the prescribed acceptance criteria. The DQIs are measures used to assess the completeness, sensitivity, accuracy, precision, comparability, and representativeness of the sample collection and sample analysis process. The output of this review was a set of alphabetic flags such as "U," "J", "R," or combinations thereof, assigned to individual results based on the validation effort. These flags were used to infer the general quality of the data and if data quality meets the DQOs of the project. The DQOs presented in the approved UFP-SAP (Tetra Tech, 2010) were maintained through the course of the sampling event. Worksheets #15 and #19 of the UFP-SAP present the analytical methods and compounds analyzed.

7.4.1.1 Data Validation Process

All of the FBL sample results were validated according to several specifications. Assignment of data qualification flags conformed to rules established in USEPA National Functional Guidelines for Organic Data Validation (October 1999), USEPA National Functional Guidelines for Inorganic Data Validation (October 2004), and DoD document entitled QSM for Environmental Laboratories (January 2006 and April 2009) to the greatest extent practicable for non-contract laboratory program data.

Several samples analyzed for various parameters were qualified due to numerous issues. Appendix D contains the data validation reports, which outline the specific qualification reasons for each sample according to the parameter.

7.4.1.2 Data Quality Review

Some of the DQIs are generated from the analysis of field samples (e.g., field duplicates) while others are from the analysis of FBL samples (e.g., laboratory duplicates). Individually, field and FBL DQIs provide measures of the performance of the respective investigative operations (field or laboratory). If individual QC results were unacceptable, there was an assignment of a validation flag indicating the type of QC deficiency impacting the result. Supporting documentation regarding the data presentation and usability for NTC Lakefront is presented in Appendix E.

7.4.1.3 Completeness

The sample collection and analytical completeness for NTC Lakefront was 90 percent. Twenty-seven of the proposed 30 samples were collected, as discussed in Section 7.2. However, the remaining samples were sufficient to meet the project goals.

7.4.1.4 Sensitivity

The PQLGs for each analyte are listed in Worksheet #15 of the UFP-SAP (Tetra Tech, 2010). One-hundred, 85, and 59 percent of TNT, HMX, and RDX sediment data points from NTC Lakefront were reported as non-detected at concentrations greater than corresponding minimum PALs because the contracted laboratory did not achieve method detection limits specified in Worksheet #15 of the UFP-SAP.

It should be noted that a high degree of analytical sensitivity was required for the explosives analyses conducted for this project. Under conditions of high sensitivity, there exists an increased potential for chemical interferences to corrupt the analysis. In addition, the laboratory experienced some apparent contamination problems. A detailed evaluation of the chromatographic data and multiple consultations with the laboratory resulted in some reported detections of explosives compounds being reclassified as non-detects. However, some of the reported detections could not be reclassified and the data suggest that the detections are artifacts of the analysis and do not represent true detections. With the available

data it is impossible to determine with confidence whether these detections are artifacts. Data validation reports explain this situation in more detail (see Appendix D).

The explosives analytical method (liquid chromatography [LC] with ultraviolet detector [UV]) that was used for this project is designed for the sample matrices for this project. Additionally, the analytical laboratory is accredited to conduct the analyses; therefore, the project team could not have anticipated these quality problems. This does not change the fact that reported target analyte detections may be artifacts. Resampling and analysis may be required if the existence of artifacts would change the project decisions. If resampling and analysis is necessary to verify the reported detections or if additional samples are collected as part of the RI process than the LC with a mass spectral detector instead of an UV detector should be utilized because the mass spectral detector has been used successfully for high explosives analyses. The sensitivities achievable are sufficient to detect explosive target analytes at PAL concentrations. Mass spectral detectors provide a greater degree of target analyte identification which helps to avoid incorrectly reporting analytical artifacts as target analyte detections.

7.4.1.5 Field and Laboratory Accuracy

There were no quality control deficiencies noted for field or FBL accuracy for NTC Lakefront.

7.4.1.6 Field and Laboratory Precision

There were no quality control deficiencies noted for the field and FBL precision in NTC Lakefront data. Field duplicate results were acceptable.

7.4.1.7 Comparability

Comparability is defined as the confidence with which one data set can be compared with another (e.g., among sampling points and among sampling events). Comparability was achieved by using standardized sampling and analysis methods, as well as standardized data reporting formats. Comparability of laboratory measurements was achieved primarily through the use and documentation of standard sampling and analytical methods. Results were reported in units that ensured comparability with current state and federal standards and guidelines. Comparability of laboratory measurements was assessed primarily through the use of QC samples and through adherence to the QA plan. The data comparability for NTC Lakefront was deemed acceptable.

7.4.1.8 Representativeness

The UFP-SAP (Tetra Tech, 2010) and the use of standardized sampling, sample handling, sample analysis, and data reporting procedures were designed so that the final data would be accurate representations of actual site conditions. Based upon the field logs indicating the conditions during sample collection and laboratory audits, all reported data are adequately representative of site conditions of NTC Lakefront.

7.5 DATA COMPARISON TO PROJECT ACTION LIMITS

7.5.1 Identification of Chemicals Exceeding Project Action Limits

Twenty-seven sediment samples collected from NTC Lakefront were submitted to the FBL for select metals (antimony, arsenic, copper, iron, lead, magnesium, strontium, and zinc) and select explosives (HMX, PETN, RDX, tetryl, and TNT) analysis.

The laboratory concentrations for the sediment samples were compared to the ecological PAL for screening purposes to determine if further investigation is necessary. In addition, the data was compared to the site-specific background sediment sample concentrations for select metals for evaluation purposes. All of the sediment samples collected from NTC Lakefront were collected 0 to 0.5 feet below the lake bottom.

Table 7-2 summarizes the laboratory analytical detection results as compared to the PALs. If a parameter exceeded its PAL at any sampling point, the parameter was highlighted.

7.5.1.1 Select Metals in Sediment within NTC Lakefront

None of the sediment samples collected from NTC Lakefront and submitted for laboratory analyses exhibited concentrations exceeding their respective ecological PALs for antimony, copper, iron, lead, magnesium, strontium, and zinc.

Arsenic

Arsenic was the only metal, which exhibited concentrations in excess of its respective PAL in the sediment samples collected from NTC Lakefront. Concentrations of arsenic ranged from 2.59 to 14.3 mg/kg. Five of the sediment samples exhibited arsenic concentrations exceeding the ecological PAL of 9.79 mg/kg (Figure 7-3 and Table 7-2). In addition, a statistical comparison of NTC Lakefront sediment

data to the site-specific upgradient/background sediment sample concentrations for arsenic was conducted (Appendix G). The evaluation indicates that the concentrations of arsenic detected in the sediment samples collected from the SDZ of NTC Lakefront are below the site-specific upgradient/background sediment sample concentrations for arsenic (Appendix G).

7.5.1.2 Select Explosives in Sediment within NTC Lakefront

Only HMX and RDX showed detected concentrations above the ecological PALs in sediment collected from NTC Lakefront. As discussed in Section 7.4.1.4, detections of these constituents in the lake sediments are highly suspect because of the laboratory method used to analyze the samples. In addition, the laboratory experienced some apparent contamination problems with the samples analyzed for the explosive constituents, suggesting that the detections are artifacts of the analysis and do not represent true detections. With the available data it is impossible to determine with confidence whether these detections are artifacts, or truly representative of actual environmental conditions.

<u>HMX</u>

HMX concentrations were detected in excess of the PAL in four of the 27 sediment samples collected from NTC Lakefront. Concentrations of HMX ranged from non-detect (<0.1 mg/kg) to 0.152 mg/kg. The four sediment samples exhibited HMX concentrations exceeding the ecological PAL of 0.0047 mg/kg (Figure 7-3 and Table 7-2).

<u>RDX</u>

RDX concentrations were detected in excess of the PAL in 11 of the 27 sediment samples collected from NTC Lakefront. Concentrations of RDX ranged from non-detect (<0.1 mg/kg) to 0.427 mg/kg. The 11 sediment samples exhibited RDX concentrations exceeding the ecological PAL of 0.013 mg/kg (Figure 7-3 and Table 7-2).

None of the sediment samples collected from NTC Lakefront, and submitted for laboratory analyses, exhibited concentrations exceeding their respective ecological PALs for PETN, tetryl, and TNT. However, 100 percent of TNT, 85 percent of HMX, and 59 percent of RDX sediment results were reported as non-detected at concentrations greater than corresponding minimum PALs because the contracted laboratory did not achieve MDLs specified on Worksheet #15 of the UFP-SAP (Tetra Tech, March 2010).

The detection limit for HMX and RDX was 0.1 mg/kg. The ecological PALs for HMX (0.0047 mg/kg) and RDX (0.013 mg/kg) are conservative screening values used in the SAP to ensure laboratory detection limits were adequate. These conservative screening values were based on equilibrium partitioning as described in Talmage et al., (1999). Equilibrium partitioning was used by Talmage et al. (1999) because no spike sediment toxicity tests were located by the authors. The recent publication by Sunahara et al., (2009), presents No Observed Effects Concentrations (NOECs) and Lowest Observed Effects Concentrations (LOECs) from spiked sediment toxicity studies for two freshwater aquatic invertebrates (*Hyalella azteca* and *Chironomus tentans*). These NOECs and LOECs were developed for several explosives in Table 5.2 of the referenced publication. NOECs are concentrations where, effects were not observed in the study and LOECs are concentrations where effects were observed. Because these NOECs and LOECs are based on empirical data they are more appropriate for determining whether the concentrations of HMX and RDX in sediment are likely to impact sediment invertebrates as compared to screening values based on equilibrium partitioning. For HMX, the NOECs ranged from 126 mg/kg to 146 mg/kg and for RDX, the NOECs ranged from 102 mg/kg to 711 mg/kg. Therefore, the site concentrations and detection limits are much lower than these NOECs and impacts to sediment invertebrates from HMX and RDX are not expected.

Although the detection limit for TNT (0.1 mg/kg) was greater than the ecological PAL (0.092 mg/kg), sediment invertebrates are not likely to be impacted by TNT for several reasons. The PAL is just slightly lower than the detection limit, so it is not likely that many samples would have TNT detections between 0.092 mg/kg and 0.1 mg/kg. It is more likely that TNT, if present, is at concentrations less than the PAL. Furthermore, the PAL is a conservative screening value used in the SAP to ensure laboratory detection limits were adequate. These conservative screening values were based on equilibrium partitioning (Talmage et al., 1999). Table 5.2 in Sunahara et al., (2009) presents NOECs and LOECs for the same two freshwater aquatic invertebrates listed above. For TNT, the NOECs ranged from <0.1 mg/kg (less than detection) to 4 mg/kg. Therefore, any of the detections would be similar to or lower than the NOECs and impacts to sediment invertebrates from TNT are not expected.

Select Metals in Sediment Upgradient of NTC Lakefront

Arsenic was the only metal, which exhibited concentrations in excess of its respective PAL in the sediment samples collected upgradient of NTC Lakefront. A concentration of 10.7 mg/kg was identified in sample UPG-010, located approximately 1,200 feet northeast of the area of NTC Lakefront. Appendix G presents a statistical evaluation of the upgradient sediment samples to the on-site NTC Lakefront sediment samples using the Wilcox Rank Sum Hypothesis test with a 5% significance level.

7.6 UPDATED CONCEPTUAL SITE MODEL

Table 7-3 contains the tabular CSM, which outlines the current understanding of NTC Lakefront. Figure 7-4 provides a graphical representation of the current understanding of the CSM for NTC Lakefront. Figures 7-5 and 7-6 identify the exposure pathways where site receptors could be exposed to, come in contact with, or be impacted by MEC and MC, respectively. Based on the analytical information obtained during the SI, MC do exist at the site based on a screening against ecological PALs. MEC/MPPEH was not identified during the SI; however, magnetic anomalies were identified but the full extent of the SDZ may not have been delineated, as discussed in the MEC SI report (Tetra Tech, 2010).

7.7 CONCLUSIONS

Arsenic was the only metal that exhibited concentrations in excess of its ecological PAL in the sediment samples collected from NTC Lakefront. However, the levels of arsenic detected within the SDZ of the site were statistically below the arsenic concentrations detected in the upgradient (background) site-specific sediment samples. Therefore, the arsenic observed within NTC Lakefront can be attributable to naturally occurring arsenic concentrations found within the lake.

The detection limits for several explosive constituents (HMX, RDX, and TNT) are similar to or much lower than NOEC based on more recent empirical data. Therefore, impacts to sediment invertebrates from explosive constituents are not expected.

7.8 RECOMMENDATIONS

Based on the results of the SI, NFA is recommended for MC (explosives and select metals) for NTC Lakefront. Further action will be necessary to ascertain whether anomalies identified during the underwater geophysical survey are MEC/MPPEH. Anomalies selected for further investigation will be determined during planning of the next phase of investigation and may include some or all of the previously sampled locations.

FIGURE 7-6

MC EXPOSURE PATHWAY ANALYSIS
NTC LAKEFRONT RANGE
NS GREAT LAKES, GREAT LAKES, ILLINOIS

Source Area	Source Medium	Release Mechanisms	Exposure Medium	Exposure Routes	Receptors				
					Current or Future				
					Military/ Civilian	Contractors/ Visitors	Construction Workers	Trespassers	Biota/ Critical Habitat
NTC Lakefront			Sediment	Ingestion	○	○	○	○	○
				Dermal Contact	○	○	○	○	○

● Complete Pathway
◐ Potentially Complete Pathway
○ Incomplete Pathway

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Guide to replacement pages

for

Site Inspection Report, (Volume II of II), for Munitions Response Program Ranges, MEC Investigation at Naval Station Great Lakes, Great Lakes, Illinois.

Section	Replacement
Acronyms	No Change
Executive Summary	**Replace Section Text**
1.0 Introduction	**Replace Section Text**
2.0 Site Description and History	**Replace Section Text**
3.0 System Configuration, Mobilization and Setup	No Change
4.0 Data Acquisition, Processing, Interpretation, And Use	**Replace Section Text**
5.0 Results	**Replace Section Text**
6.0 Conclusions and Recommendations	No Change
References	No Change
Appendices	
A Photographic Log	No Change
B Data Usability Assessment	No Change
C Multibeam (MBE) Bathymetry Data Features	**Replace Title Page**
D Data and Maps for Marine Gradiometer Array (MGA) Survey	**Replace Title Page**
Table 5-1	**Replace Table**
Other Tables	No Change
Figure 1-1 Site Location Map	**Replace Figure**
Figure 2-1 NTC Lakefront Surface Danger Zone	**Replace Figure**
Figure 4-3 Location of IVS In NSGL Harbor	**Replace Figure**

VOLUME II

REPLACEMENT PAGES AND ADDENDUM

EXECUTIVE SUMMARY

This Site Inspection (SI) Report presents the results of the geophysical investigation for one range at Naval Station Great Lakes (NSGL) in Great Lakes, Illinois. The SI was performed by Tetra Tech for Naval Facilities Engineering Command (NAVFAC) Midwest under Contract Task Order (CTO) F274 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) IV Contract Number N62472-03-D-0057.

The purpose of the SI was to evaluate the potential presence of residual munitions and explosives of concern (MEC) and/or material potentially presenting and explosive hazard (MPPEH) in the marine areas associated with historical anti-aircraft (AA) training at the Naval Training Center (NTC) Lakefront at Naval Station Great Lakes (NSGL) in Great Lakes, Illinois (Figure 1-1). The primary objectives of the SI were to determine the potential presence or absence of MEC and munitions constituents (MC) on or in the sediments at the bottom of Lake Michigan, which underlie the former anti-aircraft training range at the NTC, and to determine whether additional investigation or other action [e.g., Remedial Investigation (RI)/Feasibility Study (FS), interim action, etc.] is needed. Several activities were conducted to satisfy these objectives including:

- Performance of a multi-beam echosounder (MBE) survey.
- Performance of a marine gradiometer array (MGA) survey.
- Performance of survey verification using an underwater drop camera.

NTC Lakefront is located along the shoreline of Lake Michigan. The terrestrial portion of this site is approximately 1 acre in size and is located east of the bluff on the beachfront of Lake Michigan. The area is accessible via Ziegemeir Street, which was built over the former gun mount roundels for the training center. The water portion of NTC Lakefront is a fan-shaped area (range fan) of approximately 4,765 acres that extends out from the shoreline over Lake Michigan. The range fan extends approximately 30,000 feet east from the former firing positions. The width of the fan ranges from 1,600 feet at the shoreline to 16,000 feet at the terminus. Water depth in the fan ranges from 0 feet at the shoreline to slightly less than 120 feet at the terminus. Figure 2-1 illustrates the NTC Lakefront and the surrounding area.

Between 1942 and 1945, personnel stationed at NTC used the NTC Lakefront for AA artillery training. At that time, twenty-five gun mounts located on the beachfront were used to fire at targets being towed by airplane over Lake Michigan. The ammunition used included 20-mm, 40-mm, and 1.1-inch High

Explosive (HE), High Explosive Incendiary (HEI), High Explosive Tracers (HET) and/or HET-Dark Ignition (DI) rounds. Several million rounds were fired at cable-drawn targets towed by airplanes over Lake Michigan. The dud rate is estimated at 5 to 10 percent. Therefore, several hundred thousand rounds containing explosives may be present in the Lake Michigan sediment. The munitions fired had various ranges and it was theorized that there may be "bands" of munitions or related debris stretching across the lake bottom in the range fan.

A high resolution MBE system was first used to survey identified sampling transects in the study area. The MBE system selected provided high-resolution bathymetry and was capable of detecting and identifying features above the surface of bottom sediment. The MBE data was used to identify obstacles that might interfere with the planned geophysical survey or damage the geophysical instrumentation and to identify potential areas of interest. Following the MBE survey, a custom-designed marine gradiometer array (MGA) was used to perform an underwater geophysical survey to identify metallic anomalies on or near the sediment surface, which may be MEC or related debris/scrap. A number of the anomalies were later evaluated using an underwater video camera in an effort to visually identify the items.

During the MBE survey, over 150 line miles of data were collected and three features of interest were located in addition to numerous obstacles to the MGA survey (e.g., boulders, sand bars). One was identified as the intake structure for the NSGL power plant. A second was tentatively identified as debris from a shipwreck. The third feature of interest is a unique marine foundation made up of two sets of conical supports separated by a short distance. The purpose of this structure is currently undetermined.

During the MGA survey, over 150 line-miles of data was collected corresponding to the same areas covered in the MBE survey. This data was processed and interpreted to yield a list of 3,624 anomalies. This included all anomalies having the appropriate size for munitions fired on the former AA training range at NTC Lakefront. Analysis of the anomaly data revealed that there are three areas containing concentrated metallic debris within the range fan. These areas are located approximately 500 to 2,500, 10,000 to 14,000, and 18,000 feet from the firing line for the former range (see Figure 5-3 in the report). The inner and central depositional areas cover the width of the evaluation area at about 1,300 and 7,100 feet wide, respectively. The outer depositional area is located near the right (southern) limit of evaluation and is approximately 2,900 feet wide. Metallic debris is present at the boundaries of the evaluation area and most likely continues beyond those boundaries.

The verification survey included collection of video footage while allowing the vessel to drift in the water. Video footage was successfully recorded at all planned locations. Individual frames were isolated from the video and analyzed; however, it was not possible to identify the nature of the metallic items present

that generated the magnetic signature detected during the MGA survey. This was due in part to the fact that items on the sediment surface appeared to be encrusted with mussels.

The data and results of analyses suggest the following conclusions:

- The firing limits for the range (the north and south boundaries of the range fan) have not been fully defined.

- The terminus of the range fan (eastern boundary) appears to be relatively well defined. Even though the survey area ended about 915 feet short of the estimated maximum water depth range boundary based upon the depth limits set for the SI (i.e. water depth less than 120 feet), the amount of metallic debris had tapered off significantly, indicating that the terminal end of the range was in proximity to the end of the survey area.

- Deposition of MEC and/or MPPEH on the lake floor occurred in areas/bands roughly corresponding to the different average ranges of the various known munitions fired at the range.

- The underwater video camera did not prove to be an effective tool for target/anomaly verification, although it did provide data about lake bottom type and habitat.

Based on these considerations, additional evaluation will be needed to establish the nature and extent of potential MEC/MPPEH contamination of the former AA training range at NSGL. The following activities may be warranted:

1. Diving operations to evaluate the nature of selected metallic items identified during the MGA survey.

2. Additional marine survey and geophysical mapping of areas to the north, south, and east of the current survey area to bound (if possible) the metallic debris field [and potential unexploded ordnance (UXO)] associated with former range operations.

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

This is Volume II of the Site Inspection (SI) Report and presents the results of the geophysical investigation for one range at Naval Station Great Lakes (NSGL) in Great Lakes, Illinois. The SI was performed by Tetra Tech for Naval Facilities Engineering Command (NAVFAC) Midwest under Contract Task Order (CTO) F274 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) IV Contract Number N62472-03-D-0057.

1.2 SCOPE OF WORK

The report has been prepared to document SI activities related to the potential presence of residual munitions and explosives of concern (MEC) in the marine areas associated with historical anti-aircraft (AA) training at the Naval Training Center (NTC) Lakefront at Naval Station Great Lakes (NSGL) in Great Lakes, Illinois (Figure 1-1).

The marine munitions response site (MRS) is being investigated to assess the presence of MEC and material potentially presenting and explosive hazard (MPPEH) under the United States Department of the Navy (Navy) Munitions Response Program (MRP). In accordance with the MRP, the Navy is following the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process for investigation and remediation of the MRS.

1.3 OBJECTIVES

The primary objectives of the SI were to determine the potential presence or absence of MEC and munitions constituents (MC) on or in the sediments at the bottom of Lake Michigan, which underlie the former AA training range at the NTC, and to determine whether additional investigation or other action [e.g., Remedial Investigation (RI)/Feasibility Study (FS), interim action, etc.] is needed. Several activities were conducted to satisfy these objectives including:

- Performance of a multi-beam echosounder (MBE) survey.
- Performance of a marine gradiometer array (MGA) survey.
- Performance of survey verification using an underwater drop camera.

This report documents the SI activities and presents the results and recommendations for the path forward for the marine MRS.

1.4 REPORT ORGANIZATION

This remainder of this report is organized as follows:

Section 2.0 contains a general site history and description;

Section 3.0 contains a description of the survey system configurations and the mobilization and setup procedures;

Section 4.0 describes data acquisition and processing;

Section 5.0 presents the results of the site inspection surveys;

Section 6.0 contains conclusions and recommendations; and

Section 7.0 contains a reference list.

This report also contains the following four appendices:

Appendix A contains a photographic log documenting the activities conducted during the SI, equipment systems used, and other items of interest. Appendix B contains quality control (QC) data for the surveys. Appendix C contains the MBE data on digital video disc (DVD) and a full size map of the color imagery generated from the data. Appendix D contains the MGA data on DVD, along with a target/anomaly list and a full size map of the color-coded magnetic response data.

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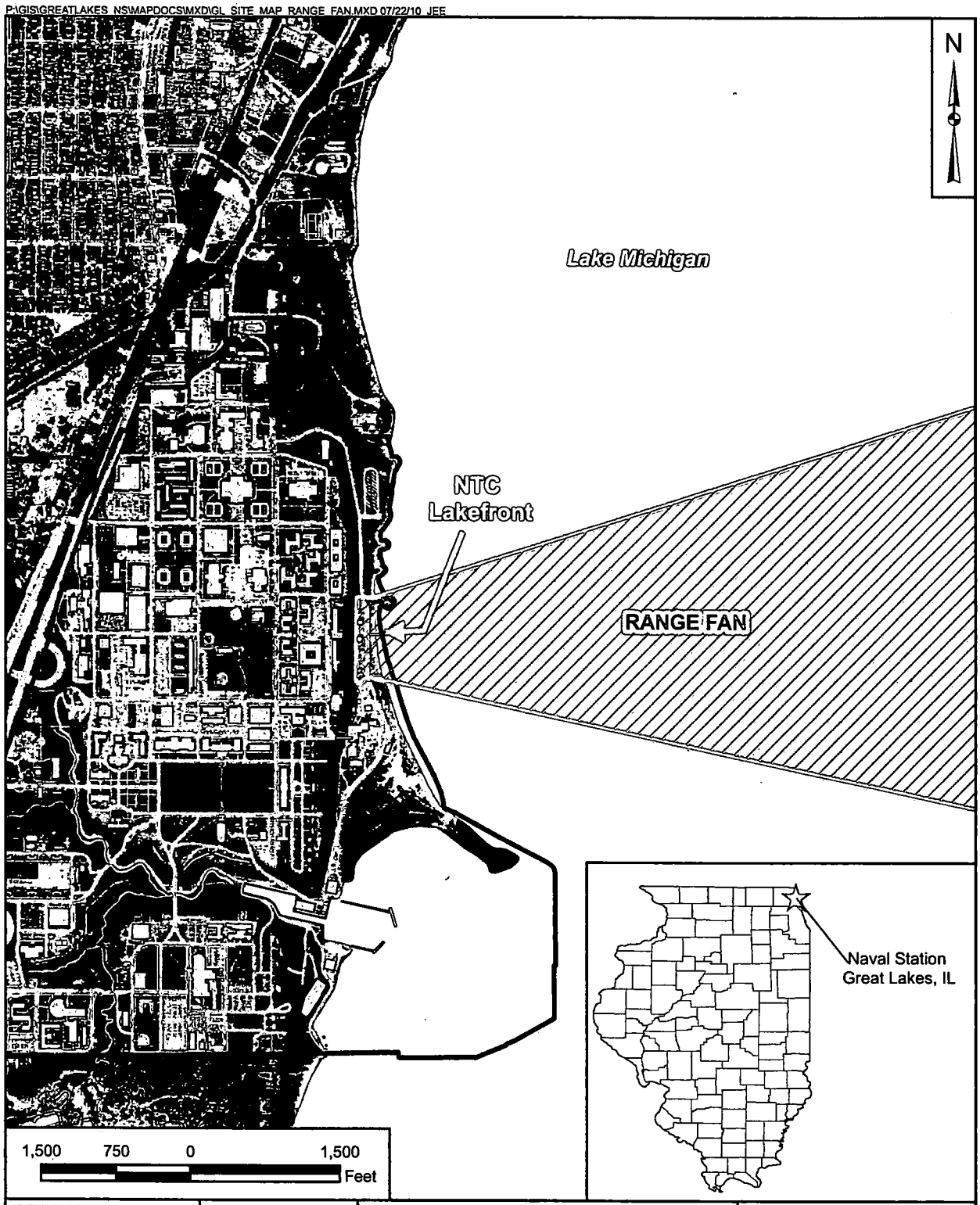

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T.WHEATON	10/23/09	NAVFAC	SITE LOCATION MAP NAVAL STATION GREAT LAKES GREAT LAKES, ILLINOIS	F274
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E. LOVE	07/22/10			—
REVISED BY	DATE			APPROVED BY / DATE
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2.0 SITE DESCRIPTION AND HISTORY

2.1 SITE DESCRIPTION

NSGL sits on approximately 1,628 acres in Great Lakes, Illinois, about 20 miles north of Chicago, in Lake County, Illinois. The installation is located along the western shores of Lake Michigan, just east of U.S. Route 41 and south of the adjacent town of North Chicago. The other population center in the vicinity is the town of Waukegan, approximately 8 miles north on U.S. Route 43. NSGL is bounded by Lake Michigan to the east and Skokie Highway (U.S. Route 43) to the west. The Shore Acres Country Club is the southern border of NSGL. Figure 1-1 shows the general location of NSGL.

NSGL is the largest active duty Department of Defense (DoD) Naval training center in the US. NSGL is home to enlisted personnel training and officer accession training. The installation is one of Illinois' largest employers with over 25,000 military and civilian personnel. The Great Lakes Naval Hospital trains 4,000 Navy Corpsmen annually and is the Navy Regional Processing Site for several hundred reservists.

NSGL provides support for the Navy through the intense training and specialized itinerary for enlisted personnel preparing for the fleet. Major commands at NSGL include Naval Station (NAVSTA), a shore activity reporting command; the Recruit Training Command, at which sailors are trained; and the Service School Command (SSC), which provides initial technical training. The SSC can also be broken down into combat systems schools, engineering systems schools, and a training department.

NTC Lakefront, which is the MRS for this SI, is located along the shoreline of Lake Michigan. The terrestrial portion of this site is approximately 1 acre in size and is located east of the bluff on the beachfront of Lake Michigan. This portion of NTC Lakefront is bordered by Lake Michigan to the east, a recreational vehicle (RV) park to the north, a bluff to the west, and the Outer Harbor and Boathouse to the south. The area is accessible via Ziegemeir Street, which was built over the former gun mount roundels for the training center. Building 120 is the present lakefront magazine, according to a March 17, 2003, listing of known ammunition storage and firing locations at NSGL. Over the years, the buildings associated with the site, including the Garage and Storage, the Machine Gun Training Building, the Armory, and the Clippings and Empties Building, were demolished. A tank farm for fuel storage was constructed at the location of the former Machine Gun Training Building at NTC Lakefront to meet the needs of the power plant sometime after 1962. No construction records for the tank farm were available to provide information regarding potential munitions findings and no visible signs of the buildings exist

today. The power plant, which is used by the current tank farm, is located approximately 500 feet from the tank farm at the original location of the NTC Lakefront.

Prior to using the Lakefront site, the Navy extended the shoreline area with fill material in order to install machine gun mounts. The topography of the NTC Lakefront greatly changes from the bluff to the lake. The bluff, which serves as the western boundary of the site, is steeply sloped and is the western boundary of the site. The former location of the AA training school buildings and firing points is presently paved over with concrete and asphalt and is generally flat. A sandy beach with a concrete breakwater to help control beach erosion is located to the east of the former gun mounts.

The water portion of NTC Lakefront is a fan-shaped area of approximately 4,765 acres that extends out from the shoreline over Lake Michigan. This area, known as the surface danger zone (SDZ) or range fan, is the area over which the trainees fired during historical training exercises. It is in this area where expended rounds, dud rounds, and MPPEH are anticipated to have been deposited as a result of the training activities. The range fan extends approximately 30,000 feet east from the former firing positions. The width of the fan ranges from 1,600 feet (approximately 0.3 mile) at the shoreline to 16,000 feet (approximately 3.2 miles) at the terminus. Water depth in the SDZ ranges from 0 foot at the shoreline to slightly less than 120 feet at the terminus. Figure 2-1 illustrates the NTC Lakefront range fan.

For purposes of the SI field investigation, the site was divided into two portions: the terrestrial portion, which includes the firing line and all structures and the water portion, which includes the range fan over Lake Michigan. This report addresses only the marine portion of the site.

2.2 SITE HISTORY

Between 1942 and 1945, personnel stationed at NTC used the NTC Lakefront for AA artillery training. At that time, twenty-five gun mounts located on the beachfront were used to fire at targets being towed by airplane over Lake Michigan.

Approximately 1,350 sailors a day were instructed in AA training using 20- and 40-millimeter (mm) and 1.1-inch guns. Several million rounds were fired at cable-drawn targets towed by airplanes over Lake Michigan. The ammunition used included 20-mm, 40-mm, and 1.1-inch High Explosive (HE), High Explosive Incendiary (HEI), High Explosive Tracers (HET) and/or HET-Dark Ignition (DI) rounds. Based on the information obtained during the data collection process, no special consideration munitions are known or suspected to have been used at the site; therefore, the NTC Lakefront is not suspected to

contain chemical warfare material filled munitions, electrically fuzed munitions, or depleted uranium associated munitions (Malcolm Pirnie 2005).

2.3 SITE CONCEPTUAL MODEL

Based upon the information available, a conceptual site model (CSM) was developed for use in the SI. This model supported the design of the field program and was later evaluated/validated using the SI data. The initial CSM is described below.

MEC may be present in Lake Michigan sediment as the result of the training operations conducted at the NTC Lakefront site. It is estimated that more than ten million rounds of ammunition were fired. The dud rate is estimated at 5 to 10 percent. Therefore, several hundred thousand rounds containing explosives may be present in the Lake Michigan sediment. Some munitions that missed the target could have automatically detonated or partially detonated as far as 3,000 yards from the firing point, meaning that MEC or MPPEH may be present at this distance from the firing point within the lake. Munitions that did not detonate at this distance may have traveled a considerable distance before impact, depending on the munitions type and typical range. Some of the munitions fired had potential ranges of up to 30,000 feet (5.68 miles). Therefore, it was theorized that there may be "bands" of munitions or related debris stretching across the lake bottom in the SDZ (range safety fan) at locations equivalent to the auto detonation distance and at other distances corresponding to impact areas associated with frequently used gun elevations or aerial target corridors. It was thought that these "bands" would more likely resemble flattened ovals, since firing would be concentrated near the center of the SDZ. Bands closer to the shore were expected to have lower density distribution with increasing density toward the middle of the SDZ. The density was expected to decrease again closer to the maximum range of the munitions items. These bands correspond to the area of secondary and primary impact based on the historical trajectory of munitions used and flight paths of the towed targets (Figure 2-1).

2.3.1 Contaminant Migration Pathways

Within the water portion of the site, MEC in the form of 20-mm and 40-mm HE rounds, 1.1-inch rounds, and associated MEC debris are expected to be located along the lake bottom within the range fan that extends over Lake Michigan. Many times these types of AA rounds used a self-destroying tracer. When the tracer detonated, it would set off the projectile burster, thereby destroying the projectile. The projectile debris would eventually settle on the lake bottom and, in the process, some MC (explosives, and metals) may have mixed into the lake water at this time. Undetonated AA rounds may corrode and decay over time, depositing explosives and metals to the lake bottom sediment. These MC may become

entrained in the water column by lake mixing activities and may be transported beyond the site boundaries. These contaminants may eventually settle out onto the lake bottom or be diluted to very low levels.

2.3.2 Receptors and Exposure Pathways

Potentially complete exposure pathways exist for surface and subsurface sediment within Lake Michigan. Navy personnel, their visitors, recreationists, and commercial anglers may be exposed to MEC in sediment while diving, fishing, or swimming. Human and ecological receptors could also be exposed to MEC via dredging activities that may take place in Lake Michigan. Wave action, internal mixing, or dredging activities may result in potential MEC in subsurface sediment being transported to the surface of the lake bottom. Figure 2-2 presents a graphical CSM of the NTC Lakefront.

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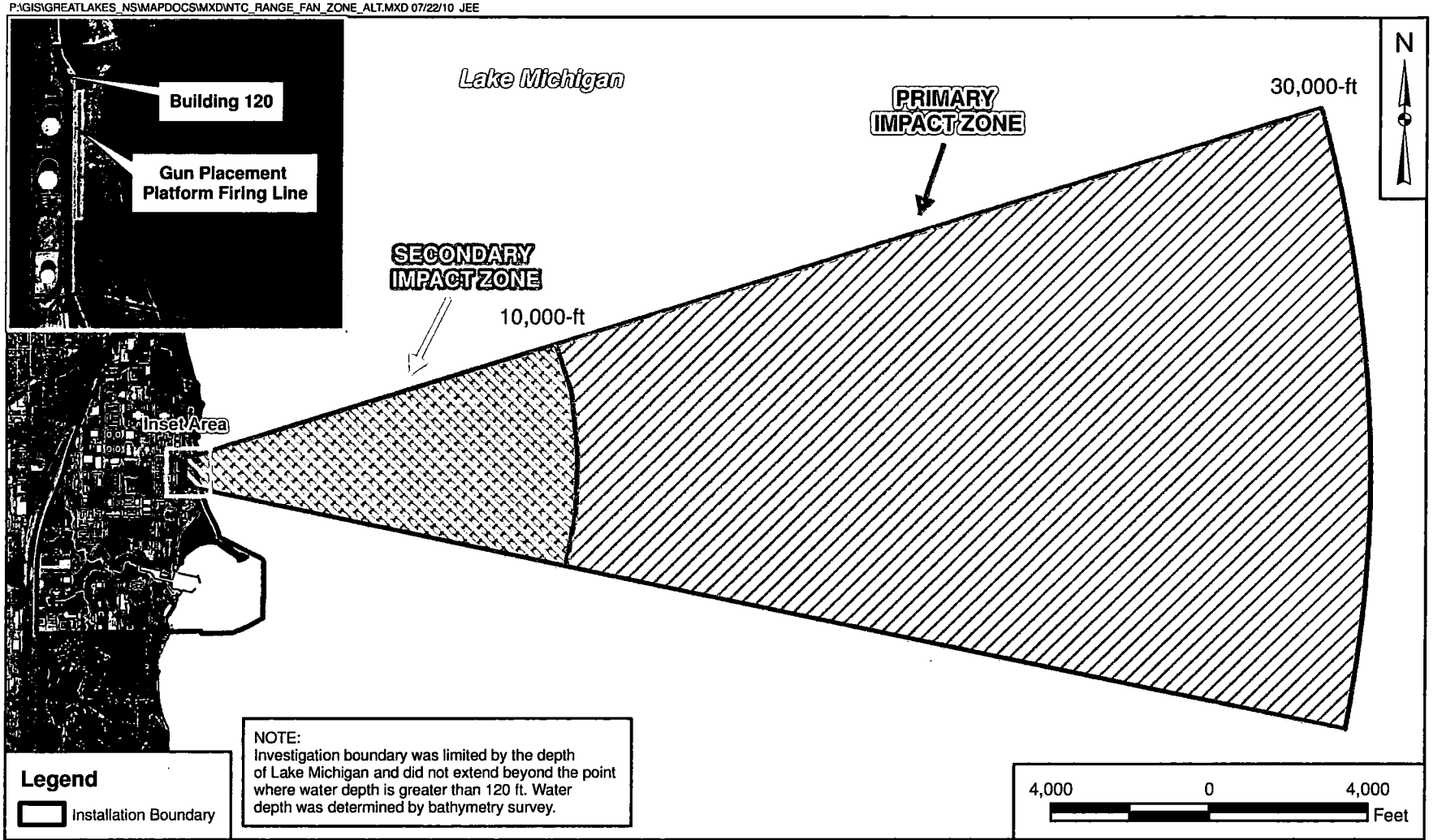

NOTE:
Investigation boundary was limited by the depth of Lake Michigan and did not extend beyond the point where water depth is greater than 120 ft. Water depth was determined by bathymetry survey.

DRAWN BY J. ENGLISH	DATE 07/22/10	NTC LAKEFRONT SURFACE DANGER ZONE (SDZ) NAVAL STATION GREAT LAKES GREAT LAKES, ILLINOIS	CONTRACT NUMBER F274
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COST/SCHEDULE AREA			APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		FIGURE NO. FIGURE 2-1 / REV 0

4.0 DATA ACQUISITION, PROCESSING, INTERPRETATION, AND USE

The boundaries for the survey were established using historical maps and data for the former AA training range at NTC Lakefront. Maps were available showing the historical SDZ that reportedly included the area between the right and left limits of fire from the firing line to the maximum range of the munitions used during training. The SDZ established for the site covers approximately 6.9 square nautical miles.

The marine surveys were conducted along a series of transects extending radially from the firing line for the historical AA training range to the terminus of the range fan, and spaced evenly to provide uniform coverage of the range fan between the right and left limits of fire. In addition, numerous cross line transects were established perpendicular to the firing line.

The use of two sets of transects, roughly perpendicular to each other, provided for cross-line ground truthing of the survey data (i.e., provided common/shared data points where the accuracy of location, sonar, and geophysical data could be compared for consistency).

Approximately 150 survey line nautical miles were surveyed in water depths ranging from 10 to 110 feet. The extreme eastern portion of the range fan (at the terminus) was not subject to survey since water depths exceeded the limit in the project scope. However, the area beyond the 110-foot depth was quite minimal. Figure 4-1 shows the SDZ and the survey transect locations. The same transects were utilized for both MBE and MGA surveys.

4.1 MBE SURVEY

4.1.1 Data Acquisition

MBE survey operations for the NSGL were conducted between April 16 and 23, 2010. Prior to the survey, all pre-survey calibration and QC operations detailed in Section 4.5 were completed to ensure collection of consistent, high-quality data. The survey was conducted in general accordance with the most recent U.S. Army Corps of Engineers (USACE) Hydrographic Surveying Engineering Manual (EM 1110-2-1003 and appendices; USACE 2002) for an acoustic multi-beam survey, as modified by the project-specific technical specifications provided in the approved Uniform Federal Policy Sampling and Analysis Plan (UFP-SAP) Volume II (Tetra Tech 2010).

The MBE survey was performed by navigating along the identified survey transects, allowing the MBE sonar to map a swath of bathymetry while ancillary systems tracked the 3 dimensional (3-D) movement of

the vessel in real time. HYPACK hydrographic software utilizing the HYSWEEP multibeam module was the primary acquisition software for the survey. This software recorded data from the various devices and displayed it in real-time for QC by the system operator. The software also provided real-time vessel navigation information to the helmsman. The line plan and vessel tracks were displayed with the multibeam swath coverage during survey operations. This gave the hydrographers immediate indications of data quality and coverage. HYPACK monitors data quality such as time syncing between device and GPS data. The software produces audible and visual alarms if data quality is outside of preset limits. Hydrographers continuously monitored HYPACK and the acquired data during acquisition to ensure data were within project specifications. The sonar was adjusted as necessary to maximize the signal to noise ratio and optimize across-track coverage by adjusting the range, power, and gain during the survey operations. Vessel speeds were also adjusted as necessary to maintain an adequate sounding density and to meet International Hydrographic Organization (IHO) Order 1A standards.

More detailed procedures for the MBE survey, including performance criteria, are available in the approved UFP-SAP Volume II (Tetra Tech 2010)

4.1.2 Data Processing

Post-processing of the multibeam data was conducted utilizing CARIS Hydrographic Information Processing (HIPS) multibeam analysis and presentation software. Further surface analyses were performed with Fledermaus Pro software. Patch test data were analyzed and any alignment corrections necessary were applied. Sound velocity profiles were generated from CTD measurements taken in the field and were used to correct slant range measurements and compensate for ray path bending.

Data processing consisted of navigation, attitude, swath, and subset editing. Navigation edits included reviewing the data for time jumps and removing abrupt vessel turns. Attitude data were reviewed for gaps and consistency. As a result of the high quality of the post processed POS Post Processing Package data, no navigation or attitude edits were necessary for this survey. Depth filtering was used to eliminate large outliers in the water column.

Processing with the swath edit mode was used to remove the remaining outlying data points clearly identified as being noise (fliers). Fliers are often the result of bottom multiples (i.e., second returns), noise due to aeration or objects in the water column, or other environmental acoustic interference. These data points were flagged as rejected and were not used in the final data set. Sounding data were not eliminated and could be re-accepted during the subset editing process. Rejected data may also have been re-accepted, if needed, to fill data gaps if they meet accuracy standards based on comparisons to

adjacent data. The number of depth cell "hits" that confirm a target above grade is three. Confirmed "targets" were retained within the database and included in all representative plots.

The HIPS subset editor and bathymetry associated with statistical error (BASE) surface creation software were the final phases of editing. Subset editing enables the hydrographer to evaluate each swath against data from overlapping survey lines while identifying potential tidal, GPS and motion artifacts. The verification of feature alignment from adjacent swaths was used to confirm sensor offsets. BASE surfaces were created to identify systematic errors or artifacts within the data set. The BASE surfaces were analyzed with multiple resolutions, sun angles, sun azimuths, and vertical exaggerations to confirm data quality. The BASE surface routine produced images representing depth, shoal-biased depth, deep-biased depth, mean depth, standard deviation, sounding density, and depth uncertainty. During acquisition in the field, editing steps were expedited to create BASE surfaces to confirm adequate multibeam coverage for each survey area and to access data quality. Comparative analysis was performed using cross-plan line depth comparisons. The multibeam survey did not cover 100 percent of the area and was primarily used to find obstructions hazardous to the MGA. Therefore, the line to line comparisons discussed above are only relevant to the data collected during the patch test and for cross-lines data in relation to the primary north-south multibeam lines.

Final exported data from the BASE surfaces included American Standard Code for Information Interchange (ASCII) XYZ text files and an Arc ASCII Grid. A final analysis was performed on the depth surfaces with the HIPS QC Report and/or Fledermaus Pro software. Final processing of the bathymetry required verified tides and was completed after field operations.

Interpretation, analysis and use of the MBE data are discussed in more detail in Section 4.3.1.

4.2 GEOPHYSICAL SURVEY

4.2.1 Data Acquisition

Geophysical survey operations for the NSGL were conducted between May 3 and 15, 2010. Prior to the survey, all pre-survey calibration and QC operations detailed in Section 4.5 were completed to ensure collection of consistent, high-quality data.

The geophysical survey was performed in much the same manner as the MBE survey by navigating along the identified survey transects and allowing the MGA to collect data while ancillary systems tracked the boat and MGA in real time. The major difference between the two survey processes is that the MGA

is not mounted to the vessel, but rather is towed astern. In addition to monitoring the position of the vessel, the geophysicist must also utilize a USBL acoustic positioning system to track the MGA and verify that the array is flying along the identified survey transect. The operator also monitors attitude and altitude sensor data from the towfish to ensure it is in the proper orientation and at the proper altitude to acquire high-quality magnetic field data. The GAPS USBL tracks the position of the MGA towfish using a pole mounted acoustic array. The position of the MGA is provided to the HYPACK software where the navigation and sensor data are integrated, recorded, and displayed in real time.

The Marine Magnetic SeaLink software was used to configure and monitor the MGA. At the start of each survey, sensors were time synchronized and configured to sample at 2 Hertz (Hz). After deploying the towfish, manual tuning was applied to the sensors to reflect the earth's ambient magnetic field strength at the survey location. For NSGL, a value to 54,000 nanotesla (nT) was applied. Sealink provided a real-time graphical display of the magnetic field strength data as well as multi-axis gradients between the MGAs sensors. The raw MGA data was also recorded in SeaLink as a backup to the data stored by HYPACK.

More detailed procedures for the MGA survey, including performance criteria are available in the approved UFP-SAP Volume II (Tetra Tech 2010)

4.2.2 Data Processing

The MGA generates multiple data streams of time series total field measurements, one for each of the seven magnetometers in the array. These data can be further processed to extract a set of difference values, or gradients, between measurements from selected pairs of sensors. Each array can be processed to derive vertical, horizontal, and lateral gradients, which can be combined to form a 3-D analytic signal. Components of the MGA data must be looked at individually as well as in total (total field) in order to identify "targets" of interest. The gradient and analytic signal data provide improved resolution and positioning over that provided by the total field data alone, will often allow the reliable detection of smaller targets, and will allow identification of multiple magnetic sources.

The MGA data was first processed with MagProc software, which merged the total field data with time coincident attitude, altitude, heading, and position data to determine the XYZ position corresponding to each sensor measurement in the selected survey coordinate system. The program also computes and georeferences the gradient and analytic signal data for each of the two arrays. MagProc outputs two file types, one with the total field and position data for each sensor, and one that includes the calculated gradient and analytic values and corresponding array positions.

Initially, the MagProc files were processed using the "find magnetic dipoles" function of Oasis Montaj on the total field data. Then the Gridpeak.gx function of Oasis Montaj software to identify anomalies (targets) meeting the specified project selection criteria (i.e., size representative of munitions of interest) in the analytic signal data.

The full data interpretation process is discussed in more detail in Section 4.3.2.

4.3 SURVEY DATA INTERPRETATION AND USE

4.3.1 MBE Data

Following processing, MBE data were used to identify and evaluate bathymetry, features of interest, and obstacles that might interfere with safe collection of geophysical data. Since the MGA "flies" relatively close to the sediment surface, it is essential to identify and avoid boulders, cultural debris, or other obstacles that might damage the equipment array or threaten the safety of the field crew aboard the survey vessel. The flight altitude of the MGA was adjusted in specific areas to prevent collisions with obstacles while still obtaining good quality data with which to locate and evaluate features of interest.

In addition, the MBE data revealed the presence of several cultural features in the survey area. This allowed the field personnel to select a "clear path" for the MGA. While the Navy was aware of an existing water intake for the NSGL power plant, they were not able to provide an exact location. The intakes appear clearly in the MBE data, highlighting an added benefit from the survey.

4.3.2 Geophysical Data

As previously stated, the geophysical data was initially interpreted using an automated target picking algorithm in the Oasis Montaj™ software. This is a preliminary interpretation, since this algorithm selects targets based only on amplitude and does not consider qualitative criteria such as signal shape. The potential target locations selected using Oasis Montaj were transcribed onto a color-coded image used for manual interpretation by an experienced geophysicist. Since the automated target picks are completely quantitative, they provided a QC check that prevented the geophysicist interpreter from being overly subjective during the manual interpretation. The results of the instrument verification strip (IVS) testing, the known characteristics of the survey area, and past experience regarding how underwater munitions appear within the geophysical data also contributed to the interpretation. Once targets were selected, they were placed on a final target list (Appendix D-11).

4.4 SURVEY VERIFICATION

An underwater video investigation of the bottom was performed using an underwater video drop camera mounted in a protective cage equipped with external liquid crystal display (LCD) light sources. This frame was equipped with a rudder that kept the camera consistently oriented while the vessel drifted over the bottom. The cage was occasionally lowered onto the sediment surface to provide closer examination of features/items of interest. The camera was flown at a constant altitude using the A-frame and winch onboard the survey vessel. Once the camera was in place, video was recorded for real-time viewing and future analysis.

4.5 QUALITY ASSURANCE/QUALITY CONTROL

To ensure that the data collected met the survey requirements, several quality assurance (QA)/QC measures were implemented, including system confidence checks prior to the start of survey operations. QA/QC measures included water level checks, lead lines, and/or bar checks. The velocity of sound through the water column was derived from conductivity, temperature, and depth measurements (CTD casts). Frequency of the sound velocity casts was conducted twice per day at a minimum, but was increased as necessary to maintain survey accuracy requirements. Spatial variability was taken into account as well as temporal variability when determining cast locations. These locations were recorded, and each cast was compared to the previous in order to identify any significant changes in the water column. During data collection, turns were limited and vessel speed was adjusted to ensure adequate seafloor ensonification and mapping. Specific QC tasks and activities for each survey element are discussed in the following sections.

4.5.1 MBE Survey

4.5.1.1 GPS Position Checks

Prior to the start of each survey day, an operator would set p the base station on the control point used for the RTK GPS. A rover GPS, identical to the one installed on the vessel, would then be taken to one or more different control points and the XYZ position reported by the rover would be compared to the published position of the control point.

4.5.1.2 GPS Azimuth Measurement Subsystem Calibration

Prior to initiating field surveys at NSGL and whenever necessary as automatically determined by the Applanix software (POSView), an alignment calibration of the Applanix POS MV motion and heading

sensor was performed. This procedure, which Applanix refers to as a GAMS calibration, utilizes software integrated into the motion sensors. The GAMS calibration procedure is initiated while the survey vessel maneuvers in a figure-eight pattern. This calibration procedure allows the POSView software to calculate offsets between the motion sensor's two GPS antennas and to align the measured heading with the vessel, resulting in achievement of the POS MV specified heading accuracies that range from 0.02 to 0.06 degree.

4.5.1.3 Water Surface Checks

The water level check compares the water level reported by the HYPACK acquisition software to the value measured at the same time by a field technician using a Leica RTK GPS rover identical to the model installed on the survey boat. This test verified proper installation offsets on the vessel and that the GPS was configured properly and receiving accurate real time corrections. The average difference for the duration of the MBE survey was 0.09 foot. Appendix B contains a detailed table of daily QC measurements.

4.5.1.4 Sonar Bar Check

The accuracy of the sonar's ability to measure a known distance was verified each day by performing a bar check. An aluminum plate affixed to a surveyor rope was lowered below the sonar to a distance measured and marked on the surveyor rope relative to the water level. A measurement was then taken with the sonar using the HYSWEEP bar check utility. Readings were corrected for draft, pitch, and roll and differences in the values were recorded. The average difference for the duration of the project was 0.1 foot (Appendix B provides a detailed table of daily QC measurements).

4.5.1.5 Multibeam Patch Test

A standard patch test, also known as an installation calibration test, was carried out prior to the MBE survey to calculate the residual angular offsets between the multibeam echosounder and the Applanix POS MV motion compensator IMU. The installation calibration process was used to derive the precise roll, pitch, and yaw angular offsets between the multibeam sonar and the local reference frame defined by IMU. The patch test was also used to determine latency in the positioning equipment. The sonar and acquisition computers are time synchronized by the Applanix POS MV GPS; as a result, there should be no latency detected between sensors.

The patch test was conducted over an area where multiple distinct bathymetry features were present and significant changes in depth occurred over short distances along track. The area selected for the patch

test was located near the entrance to the Waukegan Harbor. Pitch, roll, and yaw were measured using areas with the following characteristics:

- Roll - reciprocal lines surveyed over a flat bottom.
- Pitch - reciprocal lines surveyed over a sloping bottom, or a distinct linear feature.
- Yaw – parallel offset lines surveyed in the same direction over a sloping bottom, or a distinct linear feature.

The following table summarizes the installation offsets determined for the survey vessel

4.5.1.6 Cross-Line Comparisons

The cross-line comparison is both a measure of the system function and a data quality check. This test was performed by collecting data along lines intersecting and roughly orthogonal to the primary data collection lines. Analysis of the intersecting line data provides verification of data repeatability, and the validity of both the refraction corrections and installation linear and angular offsets. Data points co-incident to both data sets were then compared to ensure that the data was consistent. Since a large number of transects were mapped for this project and seven cross lines were established (the seven radial transects shown on Figure 4-1), a large number of data points were available for this QC comparison.

4.5.2 Magnetometer Survey

4.5.2.1 Background Test

This test evaluated system and external noise sources while the system was outside the range of any major magnetic anomalies. The test was performed by flying the array in a background area free of metal (often in mid-water column during a dive approaching a survey line). The system was allowed to collect data, which was reviewed and recorded. The geophysicist used this data to evaluate whether or not the MGA was functioning properly (i.e., that there were no large sources of noise). Statistical analysis of the data showed that for the Great Lakes Navigation System (GLNS) survey, the system operated with a low background noise level. The statistics shown on Figure 4-2 represent approximately 3 minutes of quiet data. During this time period no magnetic anomalies were observed. After applying a median filter to level and correct the data for variations in the background levels of the earth's magnetic field, all measurements were within a 2 nT range with a standard deviation of 0.33 nT.

The red line on the graph shows the uncorrected readings. The pink line shows the filtered values and the blue box (column) is the time period selected for statistical evaluation. A large magnetic target can be seen mid-line as a sharp peak.

4.5.2.2 Instrument Verification Strip

Prior to beginning the MGA survey work, the field staff installed an IVS. This verification strip provided a consistent target array used to verify the equipment function both prior to the implementation of geophysical mapping and on a daily basis during mapping. In addition to providing the basis for equipment verification, the IVS provided data on the standard response signals for the various types of munitions (either alone or in clusters) present in the test array.

The IVS for this project consisted of a plastic mat measuring approximately 4 feet by 150 feet. Actual inert munitions representative of those expected to be present in the former range area were attached to the mat either alone or in small clusters to provide an assessment of system functionality under various conditions. The mat was then deployed in an area that had been previously surveyed with the MGA and was held in place on the sediment surface using a four-point anchoring system. After deployment, the location of the IVS was determined through MBE mapping. The location of the IVS is shown on Figure 4-3. Figure 4-4 shows the construction of the IVS mat in progress (note: one of the items attached to the mat material can be seen in the photograph). Figure 4-5 shows the layout of the IVS mat including the size, number, and relative location of the items along the mat. Figure 4-6 shows examples of the seed items on the mat, including both individual and clustered items.

The area available within the Outer Harbor that had suitable water depths (10 to 20 feet) and enough buffer area for boat navigation was limited due to water depth, mooring blocks, docks and the breakwater. The area selected for use was identified using MBE mapping, which mapped water depth and indicated that the area was free of debris above the harbor bottom (e.g., mooring blocks, shoals, rocks, etc.). Once an area was identified using MBE mapping, a background geophysical survey using the MGA was conducted. This survey of the IVS area documented the presence of metal items within the area cleared by the multibeam. Due to the presence of metallic items in the area, it was not possible in all cases to discriminate individual IVS seed items from the surrounding metallic debris, which would have only been possible in an area free of background noise. However, the IVS test was run daily and QC tests confirmed positional accuracy, equipment functionality, repeatability of results, and the feasibility of detecting metallic objects in the harbor.

Figure 4-7a-f presents the IVS data summary. Figure 4-7a shows the MGA total field (TF) m Map of the IVS area prior to deploying the seed items attached to the IVS mat, while Figure 4-7c presents the analytic signal map of the IVS area prior to deployment. A small area will only few anomalies exists in the center of this map view. The IVS was deployed here, but was surrounded by numerous pre-existing anomalies, which made it difficult to locate items at each end of the IVS. A total field compilation map off all MGA IVS surveys (Figure 4-7b) shows many, if not all, of the dipole anomalies representing IVS targets. An analytic signal compilation map off all MGA IVS surveys (Figure 4-7d) also shows some of the larger IVS items as linear line of anomalies that were not present in the pre- IVS survey. Additional examples of the daily IVS surveys are shown in Figures 4-7e-f.

The magnetic anomalies seen in the IVS data collected on the May 10th and 12th are nearly identical. At least five magnetic dipole anomalies oriented perpendicular to the IVS are clearly identifiable. On both maps dipole polarization alternates consistently between each item. On May 12th, the MGA was positioned using a cable counter and layback algorithm, whereas on May 10th the MGA was positioned with the USBL. Despite using two separate positioning systems the magnetic anomalies from the IVS items are located consistently. During the data collection with the MGA tow fish, positioning was accomplished with a combination of USBL and cable counter. The magnetic anomalies seen in Figures 4-7a-f are on average 20 feet across in the along-track direction. Seed items on the IVS were only spaced at 10-foot increments, resulting in the magnetic anomalies of smaller items being masked by larger ones.

4.5.2.3 Drop Camera

Video footage was initially viewed in real time, and then replayed and reviewed in the office. The footage was re-played on a computer monitor with the screen image size ranging from approximately 9 inches by 12 inches to approximately 10 inches by 14 inches (full screen mode) by the project geophysicist, project scientists, and by Tetra Tech UXO personnel. No MEC items were identified in the drop camera video. However, given the cloudiness of the water, heavily populated mussel habitat, and sandy bottom this was expected. The gently rolling waves of the lake caused the camera to move up and down in the water column, obscuring the camera's view by disturbing the soft silty-sand bottom and by moving in and out of focus. Furthermore, the survey conditions (wind and current direction, boat maneuverability, etc.) prevented the surveyors from directly guiding the camera onto selected targets.

P:\GIS\GREATLAKES_NS\MAPDOCS\MXD\HARBOR_IVS.MXD 07/23/10 JEE

DRAWN BY J. ENGLISH	DATE 07/22/10	LOCATION OF IVS IN NSGL HARBOR NAVAL STATION GREAT LAKES GREAT LAKES, ILLINOIS	CONTRACT NUMBER —
CHECKED BY E. LOVE	DATE 07/23/10		APPROVED BY — DATE —
REVISED BY —	DATE —		APPROVED BY — DATE —
SCALE AS NOTED	NAVFAC		FIGURE NO. FIGURE 4-3 REV 0

5.0 RESULTS

5.1 MULTIBEAM ECHOSOUNDER SURVEY

MBE data was successfully obtained along all planned transect lines, with the exception of near-shore areas where water depths were less than approximately 10 feet. This resulted in the collection of (150 line-miles) of data. The MBE data met all specifications called out in the approved UFP-SAP and provided clear and detailed imagery of the bottom conditions in the survey area. The processed MBE data is presented on DVD in Appendix C. Figure 5-1 contains a full- size figure of the MBE imagery.

Using the MBE data, three specific features of interest were identified, along with numerous obstacles (boulders, etc.). In addition, the MBE data revealed the presence of various geological features such as sand ridges, sand waves, and gravel/boulder zones (Figure 5-1 and Appendix C). The three large cultural features of interest identified in the MBE data are listed and described in Table 5-1. Images of the features are presented on Figure 5-1 and Appendix C. All three of these features produced very large magnetic anomalies. Both the marine foundation and the water intake structure were accompanied by linear magnetic anomalies running toward shore. These anomalies potentially represent pipelines or cables.

5.2 GEOPHYSICAL SURVEY

Geophysical data was successfully collected along all transects surveyed during MBE survey operations. This resulted in the collection of 150 line-miles of data. The geophysical data met all specifications called out in the approved UFP-SAP. The processed MGA data is presented on DVD in Appendix D. This appendix also contains a full size figure of the color- coded, magnetic signature MGA imagery.

Initially the geophysical data was processed and interpreted to yield a list of 3,624 anomalies. The anomaly list was generated using Geosoft's Oasis Montaj software "Find Peak Dipoles" function. All dipoles with a minimum of a 2 nT peak (positive or negative pole peak) with less than a 20- foot dipole separation were picked. This included all anomalies having the appropriate size for munitions fired on the former AA training range at NTC Lakefront. After this initial target picking of the total field data, the Gridpeak.gx function of Oasis Montaj software was used to identify anomalies (targets) meeting the specified project selection criteria (i.e., size representative of munitions of interest) in the analytic signal data. The anomalies that met the criteria are listed and shown on the MGA imagery figure in Appendix D. The analytic signal noise threshold was determined to be 1 nT or less by analyzing areas with few anomalies that were representative of background. Figure 5-2 shows examples of the noise threshold

statistics, with a mean of 0.22 - 0.5 nT, and a standard deviation of 0.13 - 0.27 nT. Targets were then selected if they had a peak value over 2 nT. The IVS results at the site did not allow for the calculation of anomaly size based on item, but based on previous IVS data collected by Tt a prioritization was conducted based on anomaly peak only. During the previous IVS testing, at another site, analytic signal peak values were recorded for the following range of items: single 20 mm and 40 mm projectiles, full single 20 mm and 40 mm, as well as clusters of 20 mm and 40 mm projectiles ranged from 2 nT to 15 nT. This is the basis of our prioritization. The anomalies were then prioritized based on peak values.

Target anomalies with a larger peak than 15 nT are not considered to likely be due to AA rounds or clusters of AA rounds. The target table in Appendix D-11 shows the prioritized list of 10,205 targets. Target anomalies that were larger than 15 nT have been given a low priority of "0" while those from 2-15 nT were given a priority of "1". There are 859 priority 0 and 9,346 priority 1 targets present. Since the targets were picked along both MGA analytic signal profiles (one from the starboard side, and one for the port) there are many targets that are potentially duplicates (especially the larger target anomalies, as they will be seen by both sides of the MGA).

Analysis of the color imagery and interpretation results indicated that, as anticipated based on historical information regarding munitions fired at the range, there are distinct bands of metallic debris present at several locations in the range fan. Specifically, there are three areas containing concentrated metallic debris. These areas are located approximately 500 to 2,500, 10,000 to 14,000, and 18,000 feet from the firing line for the former range (see Figure 5-3 and Appendix D). The inner and central depositional areas cover the width of the evaluation areas, which are about 1,300 and 7,100 feet wide, respectively. The outer depositional area is located near the right (southern) limit of evaluation and is approximately 2,900 feet wide. Metallic debris is present at the boundaries of the evaluation area and most likely continues beyond those boundaries.

While the areas of concentrated metallic debris can be seen in the general concentration of anomalies in the total field data (Appendix D-1), there is also an overall signature that can be seen in the analytic signal data (Figure 5-4, Appendix D-7a and D-7b). The analytic signal response is elevated just east of the start of the primary impact zone out to approximately 16,000 feet from shore. This corresponds well with the area that should contain the most MEC fall out from properly functioning AA fire. The analytic signal appears to be picking up numerous very small targets (~1-3 nT) that are likely caused by the concentration of AA shell fragments present.

5.3 VERIFICATION SURVEY

The verification survey included collection of video footage (as discussed in Section 4.4) while allowing the vessel to drift in the water. Several attempts were made to drift over target locations in various portions of the SDZ. Video footage was successfully recorded at all planned locations. Individual frames were isolated from the video and analyzed; however, it was not possible to identify the nature of the metallic items present that generated the magnetic signature detected during the MGA survey. This was due in part to the fact that items on the sediment surface appeared to be encrusted with mussels. Figure 5-5 shows a still photograph isolated from the video footage recorded at one location in the SDZ. Shell debris is present; however, the source of the magnetic signature at this site cannot be determined from the photograph. All available video footage collected during the verification survey is presented in Appendix A (DVD).

TABLE 5-1

FEATURES IDENTIFIED USING MBE DATA

Feature	Distance Offshore	Location in SDZ	Description
Intake Structure	~7,700 ft.	Inner 1/3 of range near the right (southern) limit of fire	Three intake ports running from the structure to the shoreline in the vicinity of the NSGL power plant. Navy personnel indicated that such a structure was present, but were unable to provide an exact location.
Marine Foundation	~6,800 ft.	Inner 1/3 of range near the left (northern) limit of fire	Underwater foundation structure consisting of two sets of three cone-like structures (25 ft diameter, 6 ft height) separated by approx. 30 feet. The relative location of the two sets of supports suggests the former structure had an east-west orientation (roughly parallel to the firing line for the former range)
Suspected Ship Debris	~3,300 ft.	Inner 1/8 of range near the left (southern) limit of fire	Cluster of large metallic debris items, shapes suggest ship debris.

APPENDIX C

DATA AND MAPS FOR MULTIBEAM ECHOSOUNDER SONAR (MBE) SURVEY

(Data provided on DVD)

Appendix C-1

Multibeam (MBE) Bathymetry Data Features

APPENDIX D

DATA AND MAPS FOR MARINE GRADIOMETER ARRAY (MGA) SURVEY

(Data provided on DVD)

Addendum To:
Site Inspection Report
(Volume II of II)

for

Munitions Response Program
Ranges

MEC Investigation

Naval Station Great Lakes
Great Lakes, Illinois

Naval Facilities Engineering Command
Midwest

Naval Facilities Engineering Command Midwest

Contract Number N62472-03-D-0057

Contract Task Order F274

November 2010

081006/P (Addendum)

ADDENDUM TO:
SITE INSPECTION REPORT

MUNITION RESPONSE PROGRAM RANGES

NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

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Naval Facilities Engineering Command Midwest
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Contract Number N62472-03-D-0057
Contract Task Order F274

NOVEMBER 2010

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ACRONYMS

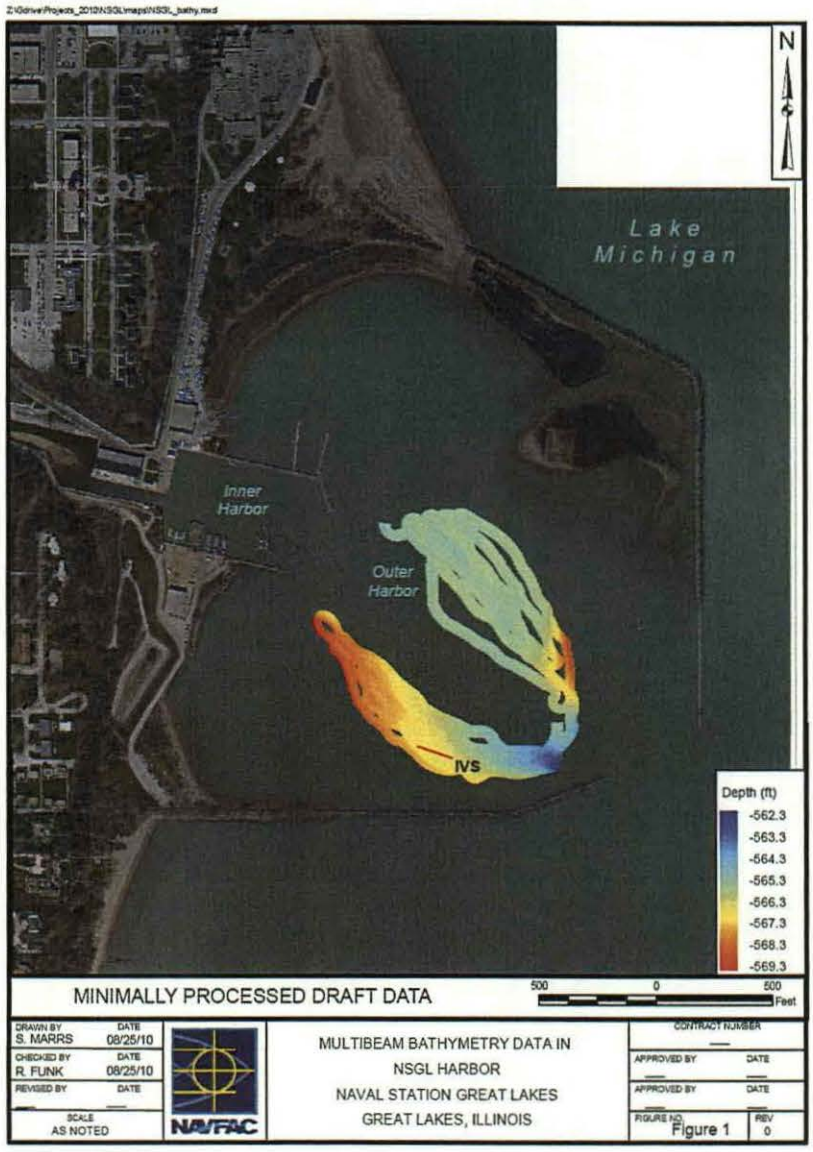
GPS	Global Positioning System
HDPE	High-Density Polyethylene
IVS	Instrument Verification Strip
MBE	Multibeam Echosounder
MEC	Munitions and Explosives of Concern
MGA	Marine Gradiometer Array
MPPEH	Munitions Potentially Presenting an Explosive Hazard
m	Meter
mV	millivolts
NSGL	Naval Station Great Lakes
nT	nanotesla
RTK	Real-Time Kinematic
UFP-SAP	Uniform Federal Policy Sampling and Analysis Plan

Note: The Addendum to the Site Inspection Report (Volume II) for Munitions Response Program Ranges at Naval Station Great Lakes was developed in response to comments received from Brian Conrath regarding the utilization and quality of the Instrument Verification Strip (IVS). This Addendum contains the results of the daily IVS quality control (QC) check that confirmed positional accuracy, equipment functionality, repeatability of results, and the feasibility of detecting metallic objects in the harbor. A daily cross line QC test is also discussed which supplemented the IVS and verified system accuracy and repeatability during data collection.

Quality Control Analysis for MGA Survey Operations at NTCGL.

Instrument Verification Strip

The outer harbor was identified during project planning as the preferred locations for the instrument verification strip (IVS). This area was selected as it provided protection from elevated sea state and disturbance from recreational boaters; furthermore, the selected area was close to but outside the project survey area (Figure 1). At the start of the project, a location within the outer harbor was selected for conducting daily IVS checks using bathymetry data acquired with a multibeam echosounder (MBE). This MBE pre-survey mapped the water depths and any debris, which was above the harbor bottom (e.g. sediment/water interface) (Figure 1). An area suitably free of debris proud of the bottom, which could damage the underwater arrays (i.e. towfish) was selected.



Once an area inside the outer harbor was surveyed with the MBE, a magnetometer survey was conducted with the Marine Gradiometer Array (MGA) to identify a suitable location, with minimal magnetic clutter, for installation of the IVS. The results of this survey are shown in Figure 2.

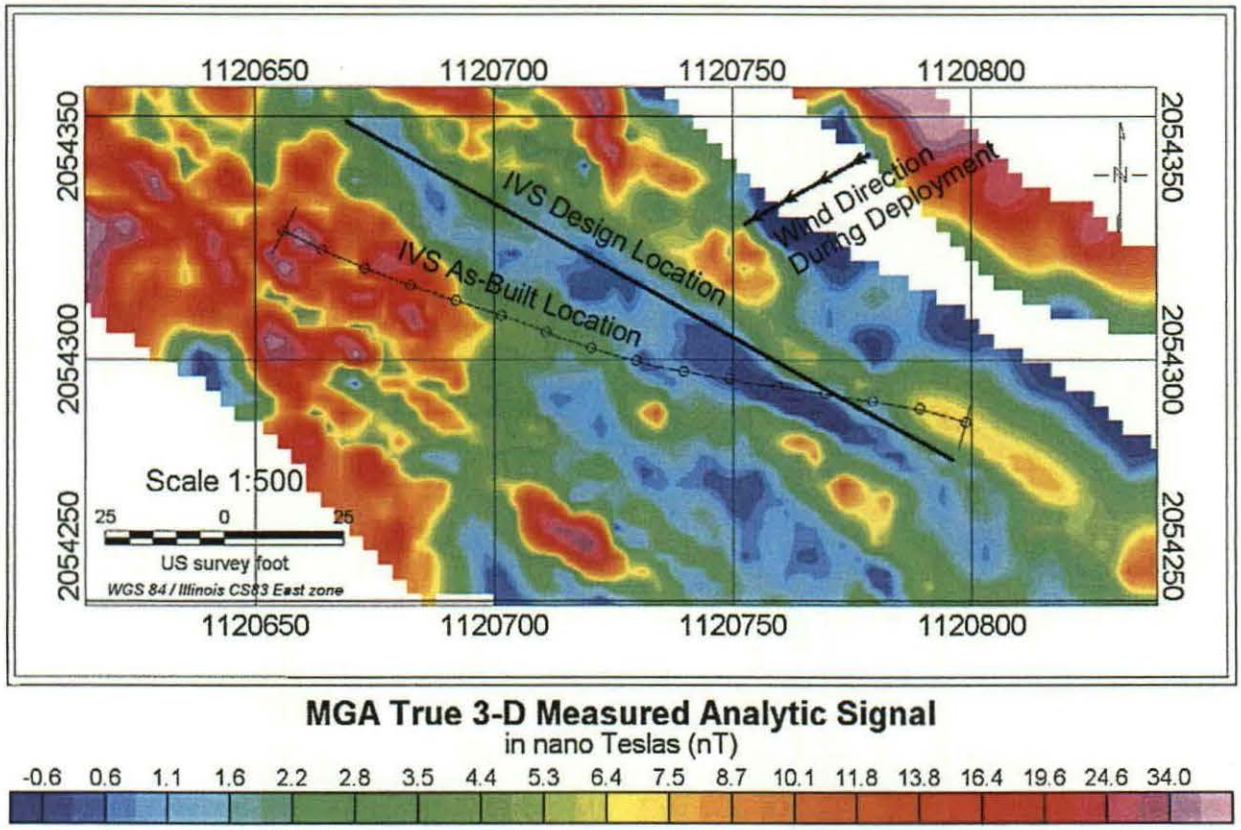


Figure 2. MGA data plot of the IVS area pre-deployment in the NTCGL outer harbor.

The available area within the outer harbor with sufficient depth and suitable run-in and turn around area was limited. The final location that was selected kept the IVS out of the navigation channel of the harbor and was the only area that could logistically work. This was a very small area that in some places was only 20 feet wide. During installation, the IVS was deployed off the stern of the R/V Ugle Duckling starting in the southeast end proceeding to the northwest end. The wind was blowing out of the northeast during the deployment. Because of the crosswind and necessary slow vessel speed during deployment, the placement of the IVS mat was skewed south of the desired location approximately 25 feet. The decision was made that the shift was acceptable as any attempt to retrieve the IVS and redeploy could damage the IVS and would likely result in similar if not worse positioning.

The IVS was constructed on a 150-foot long 4-foot wide high-density polyethylene (HDPE) aquaculture mat. IVS items were secured to sections of HDPE marine board and then these boards were attached to the mat (Figures 3 and 4).

Figure 3 IVS handling and deployment

The IVS deployed in NTCGL was composed of both inert MEC and surrogate items (Figure 4)

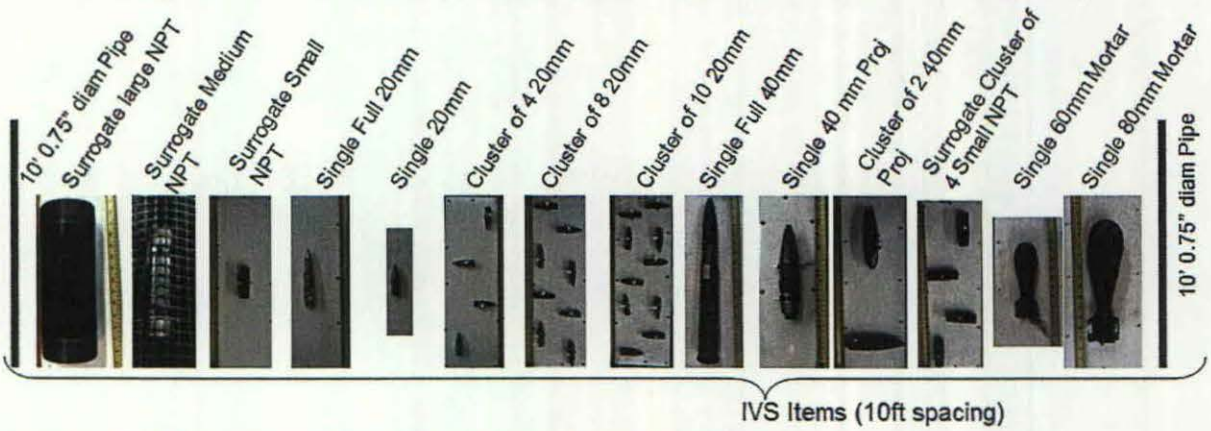


Figure 4. 150 foot long IVS mat item layout (10 ft inter-item spacing).

After the IVS was deployed, another MBE survey was conducted to accurately locate the IVS mat on the harbor bottom. Figure 5 shows the results of the post deployment survey.

The multibeam survey of the IVS was able to "see" the IVS and the affixed corner markers clearly. The positions of the individual seed items were determined from the multibeam data. Figure 5 shows a multibeam image of the IVS with seed item location symbolized. Note that other objects to the west and northeast of the IVS, which are above the bottom, can be seen in this image.

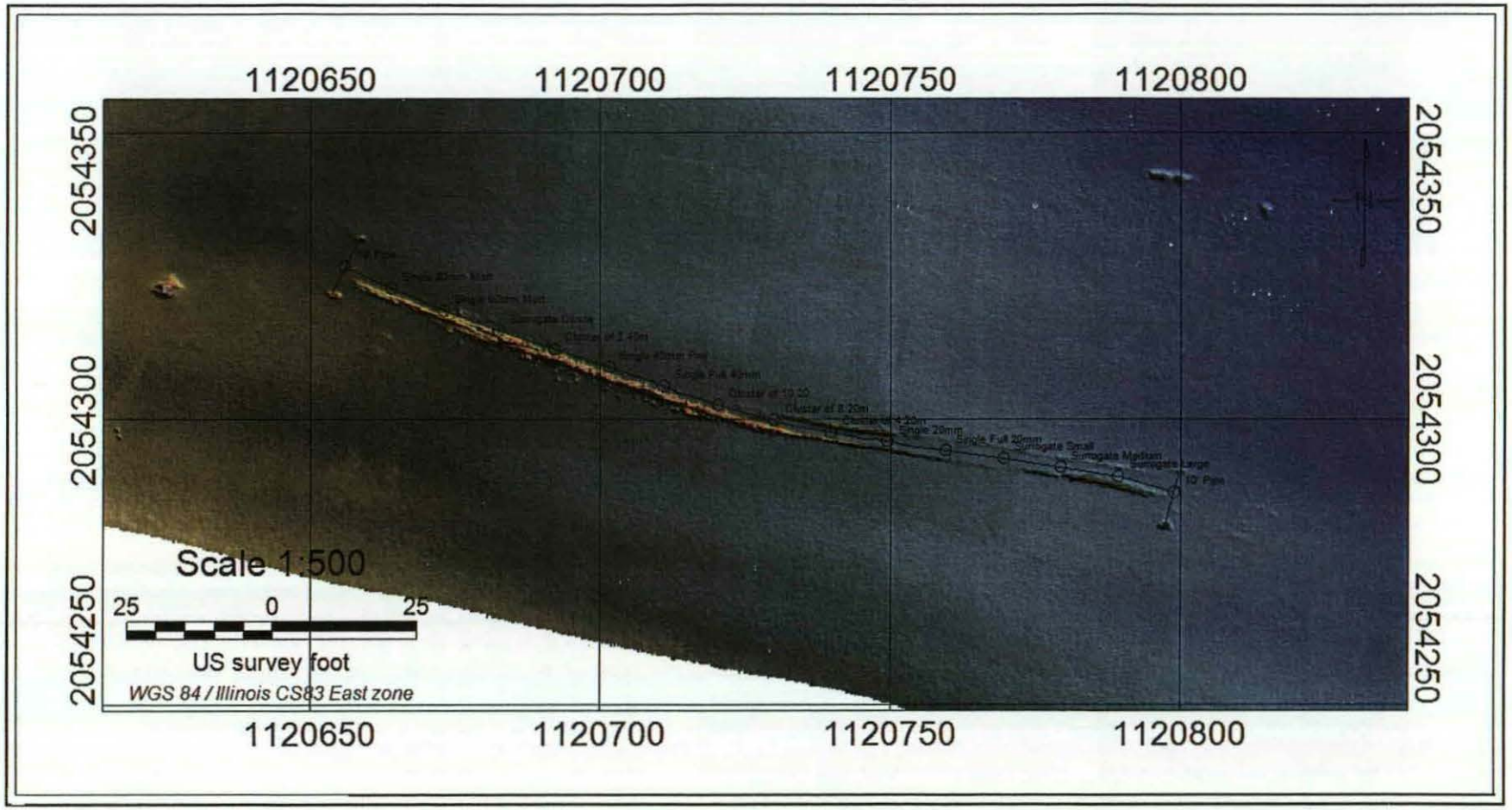


Figure 5. Multibeam image of the IVS as deployed in the NTCGL outer harbor.

Based on the MGA data (Figures 2 and 6) it is apparent that many of the pre-existing items in the vicinity of the IVS have a metallic component. Due to the concentration of metallic items within the harbor, it was not possible, in all cases, to discriminate individual IVS seed items from the background metallic clutter.

Figures 6a through 6l show the analytic signal plots for data collected over the IVS each survey day. All plots are shown using the same range color scale as shown in Figure 2. Variations in signal level are likely a result of differences in towfish altitude and position during collection. Detectable signal levels are inversely proportional to the cube of the range, so small variations in range or lateral offset can have significant effects in the resulting data.

Figure 6a shows an MGA survey of the IVS performed on May 2, 2010. While the IVS items clearly created an elevated response, the distinction of individual items is obstructed by the other large magnetic anomalies in proximity to the IVS.

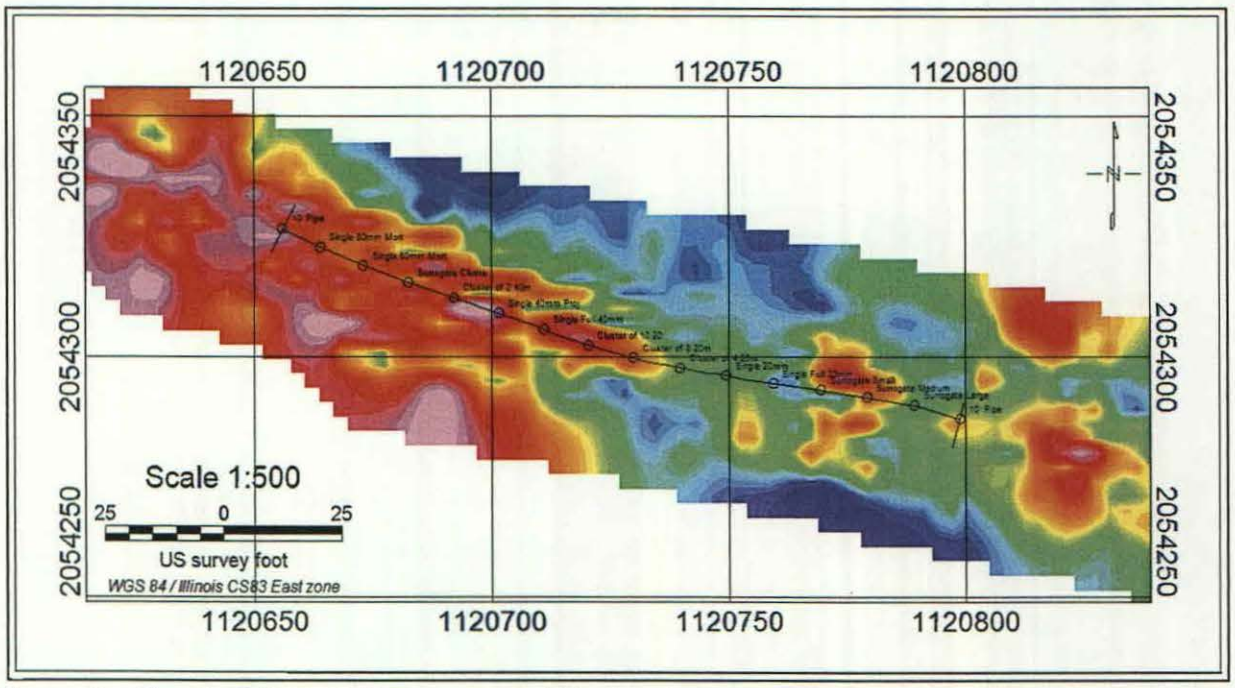


Figure 6a. May 2, 2010 MGA IVS survey, analytic signal.

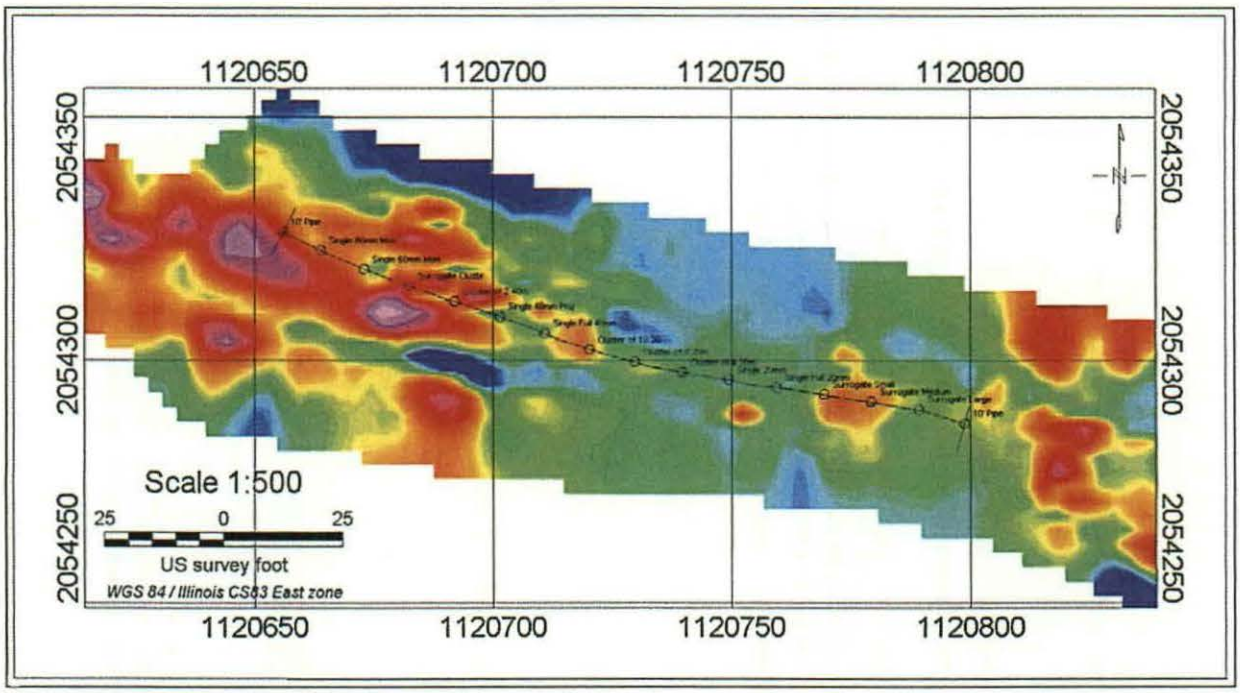


Figure 6b May 3, 2010 MGA IVS survey, analytic signal.

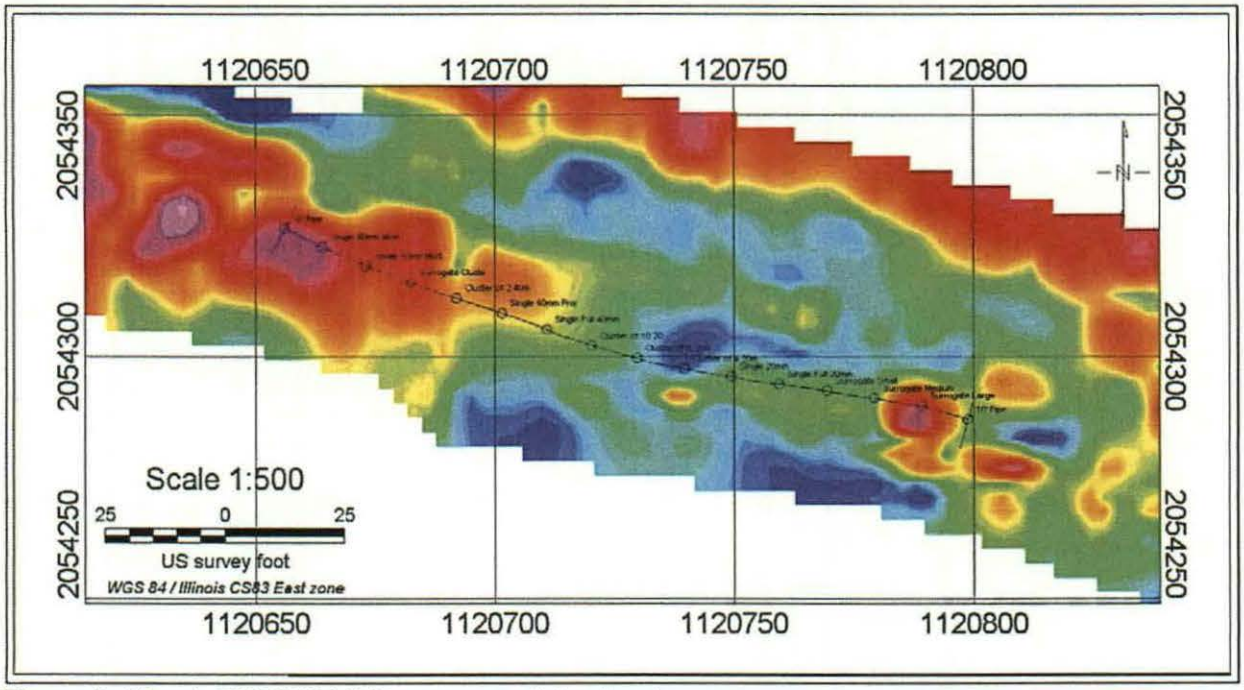


Figure 6c May 4, 2010 MGA IVS survey, analytic signal.

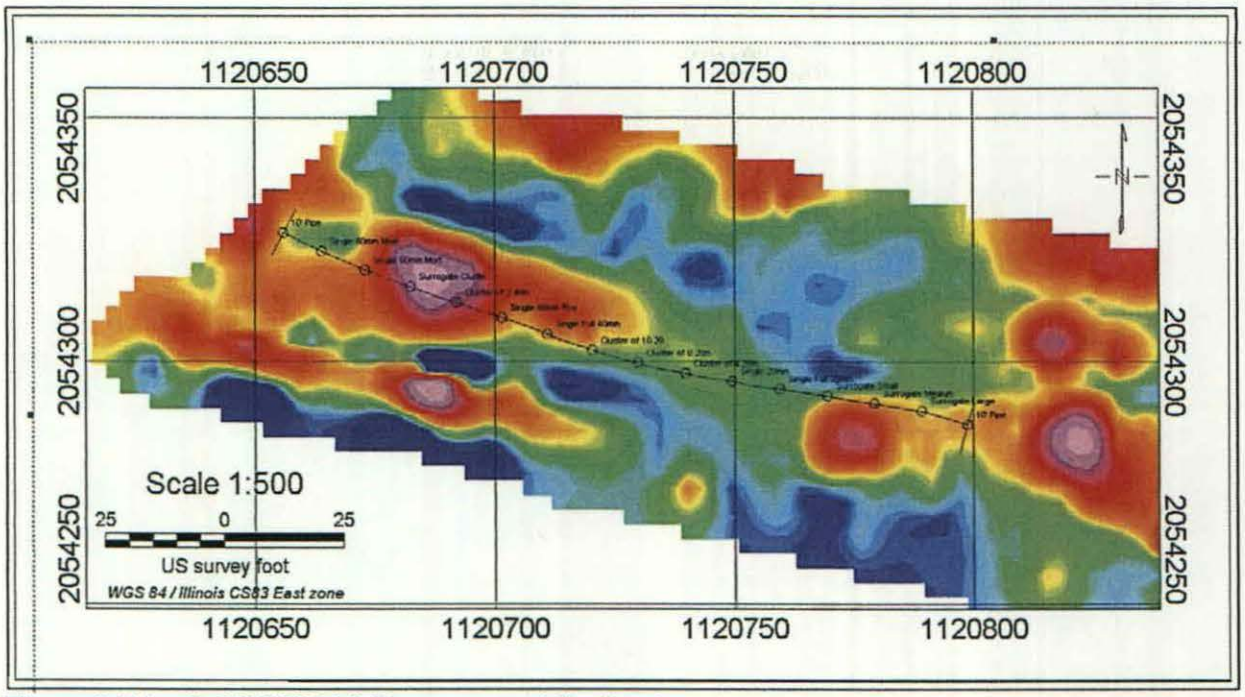


Figure 6d May 5, 2010 MGA IVS survey, analytic signal.

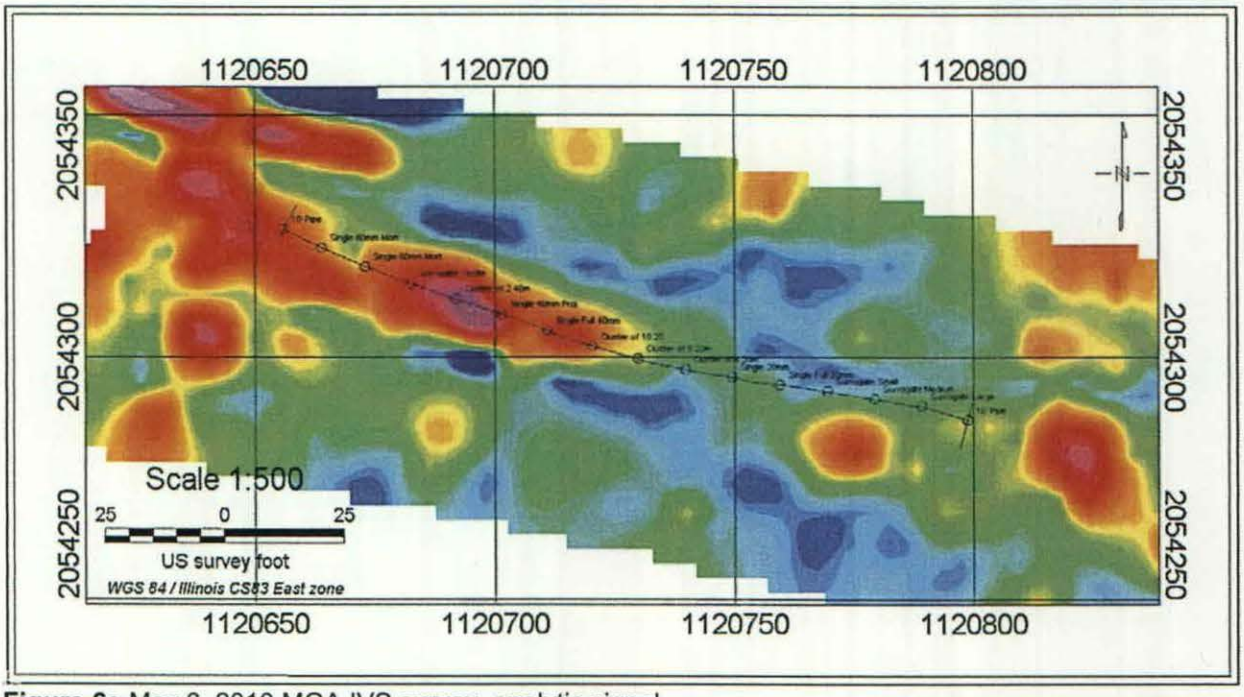


Figure 6e May 6, 2010 MGA IVS survey, analytic signal.

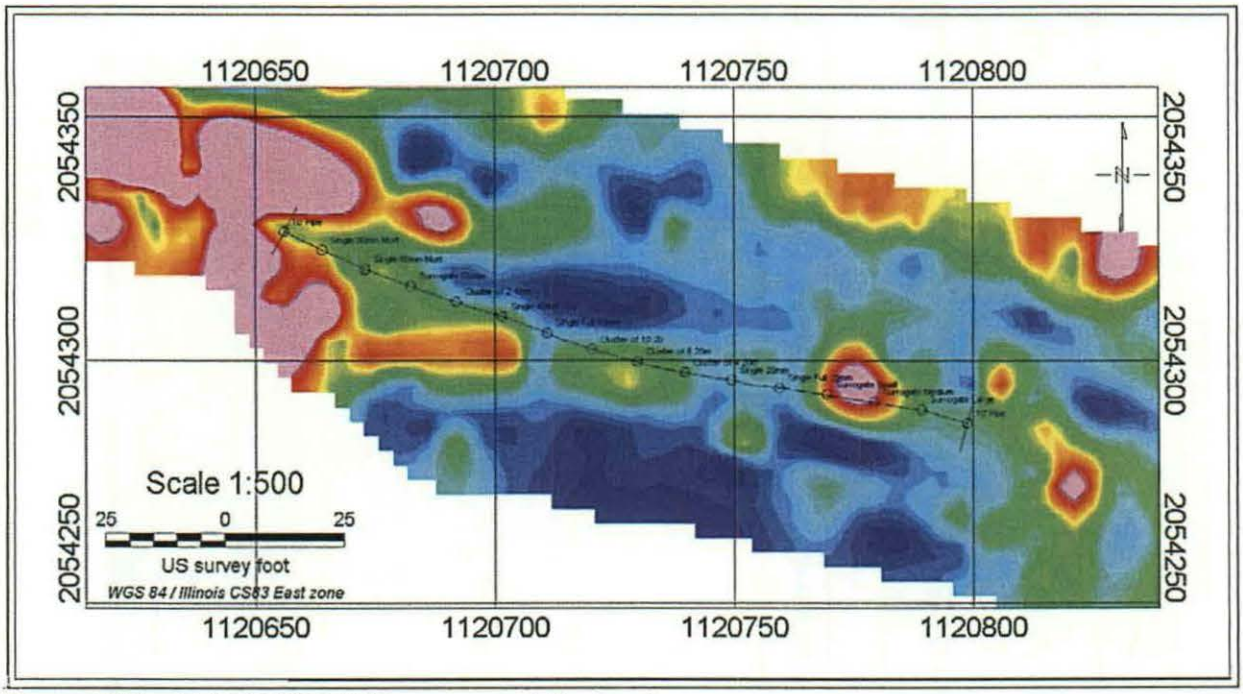


Figure 6f May 7, 2010 MGA IVS survey, analytic signal.

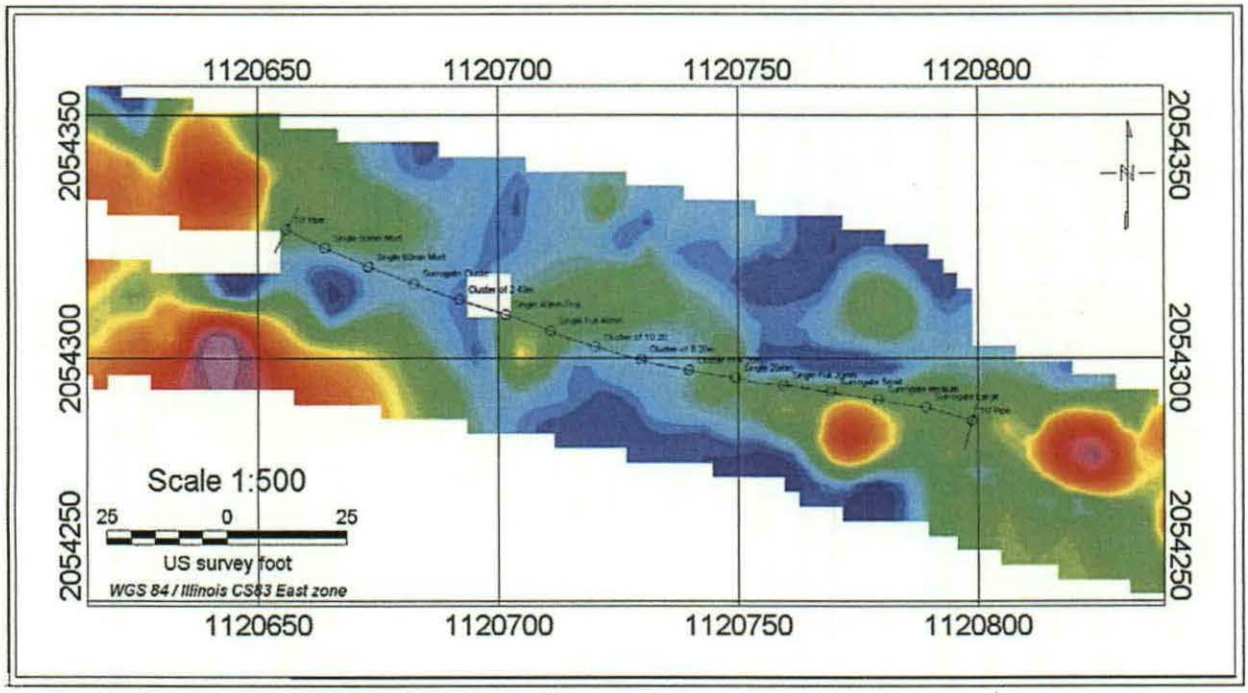


Figure 6g May 9, 2010 MGA IVS survey, analytic signal.

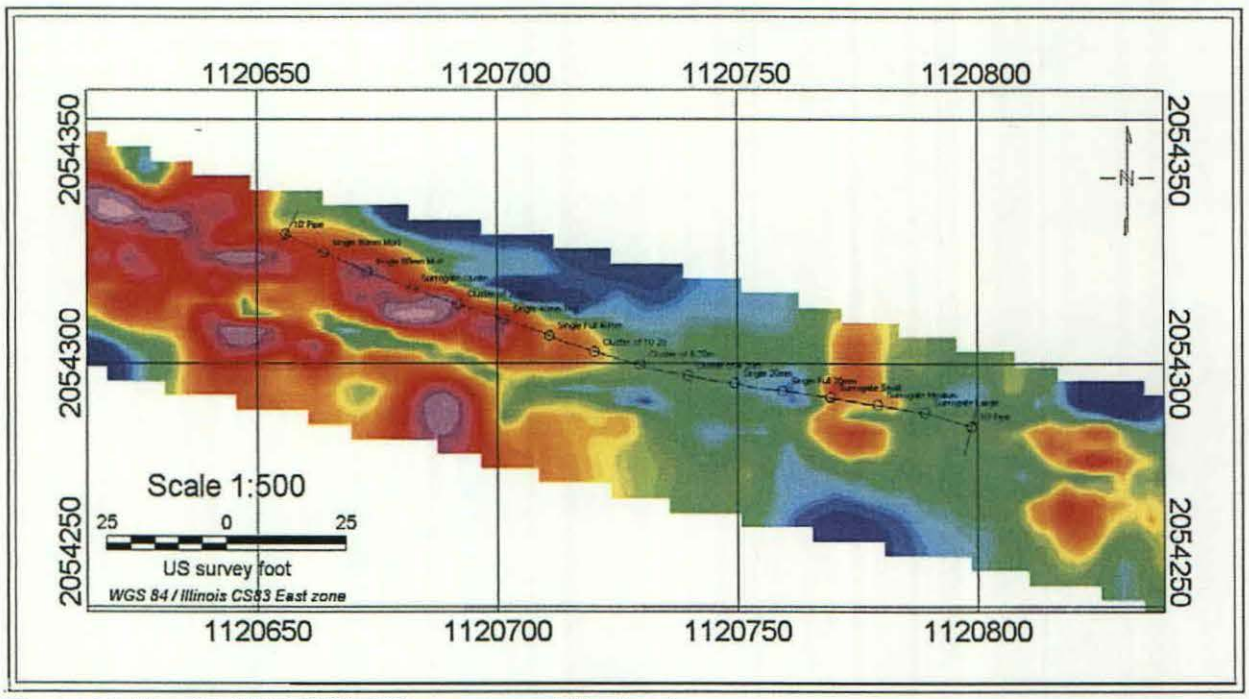


Figure 6h May 10, 2010 MGA IVS survey, analytic signal.

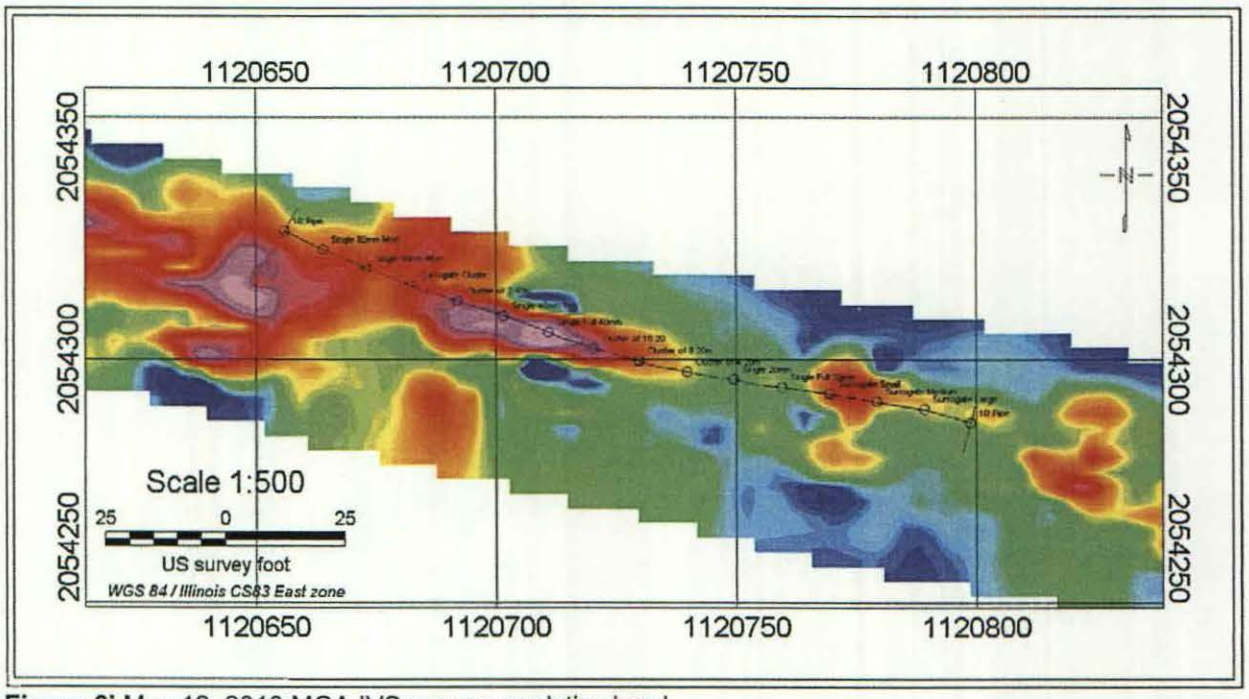


Figure 6i May 12, 2010 MGA IVS survey, analytic signal.

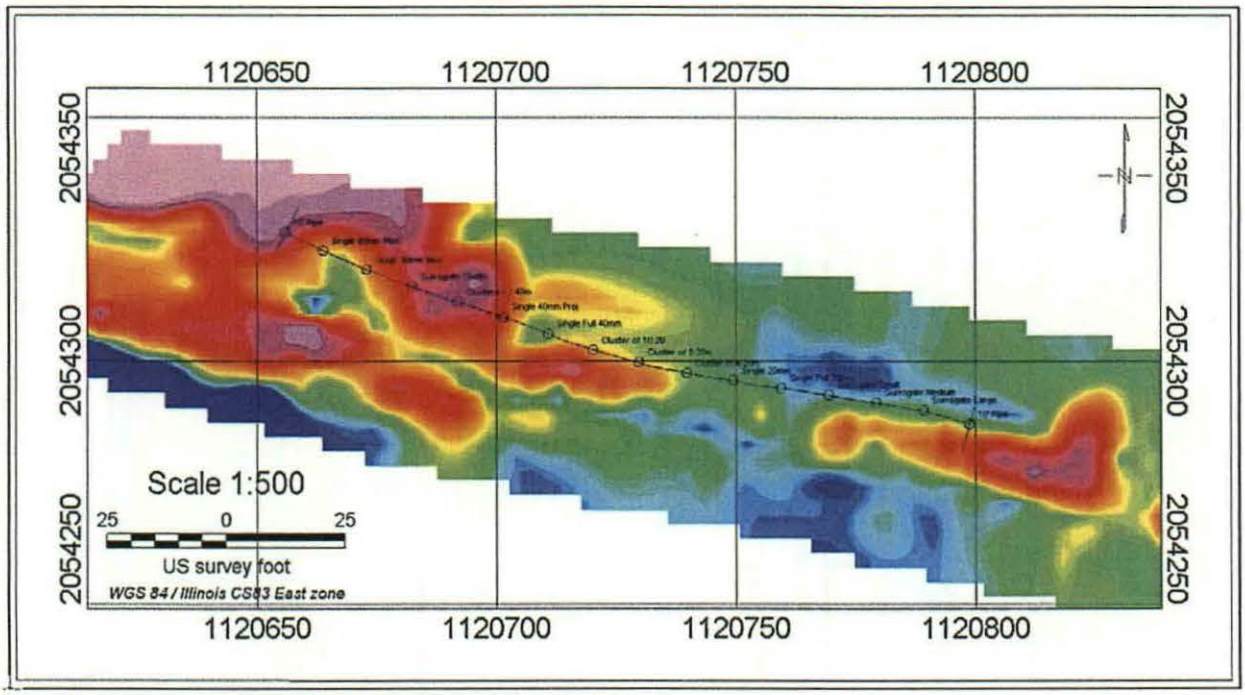


Figure 6j May 13, 2010 MGA IVS survey, analytic signal.

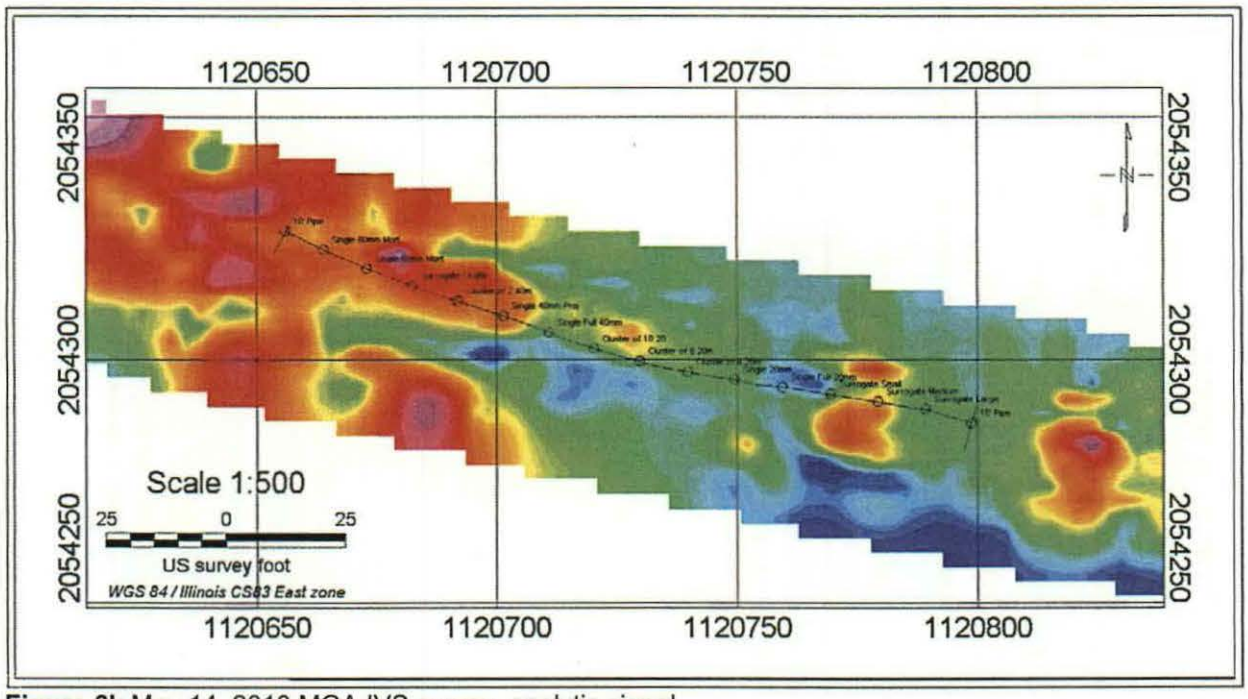


Figure 6k May 14, 2010 MGA IVS survey, analytic signal.

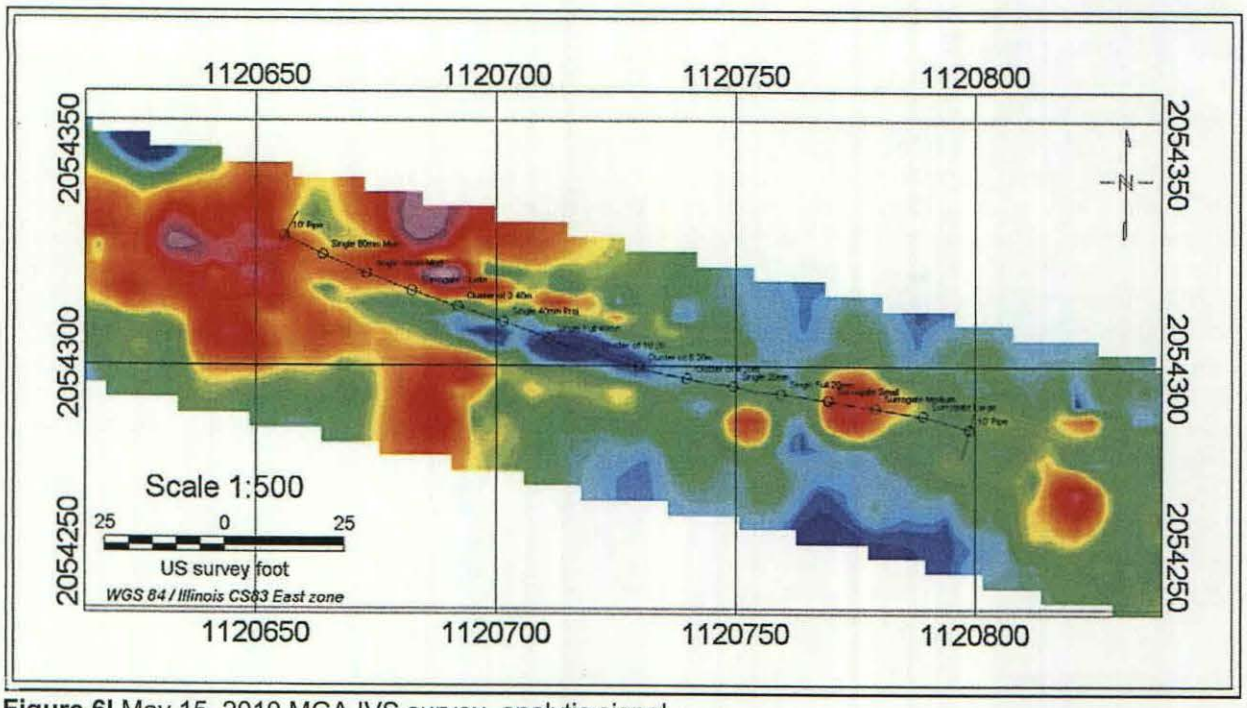


Figure 6I May 15, 2010 MGA IVS survey, analytic signal.

Cross Line Analysis

To supplement the IVS and to verify system accuracy and repeatability, at least one crossing point was analyzed each day. Data from different days were compared to check for consistency between days. When available, data from the same day was assessed for self consistency (i.e. repeatability). The analytic signal was used for this analysis, so at each crossing point there are actually four intersections as each pass consists of a port and starboard sensor array. Figure 7 shows a typical intersection between a north-south trending line and an east-west trending cross line. For simplicity, the intersections were assigned numbers as shown in Figure 7. By assessing all four crossing points, we were effectively checking both sides of the array against themselves (i.e. port vs. port and starboard vs. starboard) and against the opposite side of the array (i.e. port vs. starboard). When assessing an individual crossing point the nearest sample location to the intersection is selected. Because the all track samples are usually 2.5 ft apart, the distance between the two samples could be up to 1.8 ft apart assuming an orthogonal intersection.

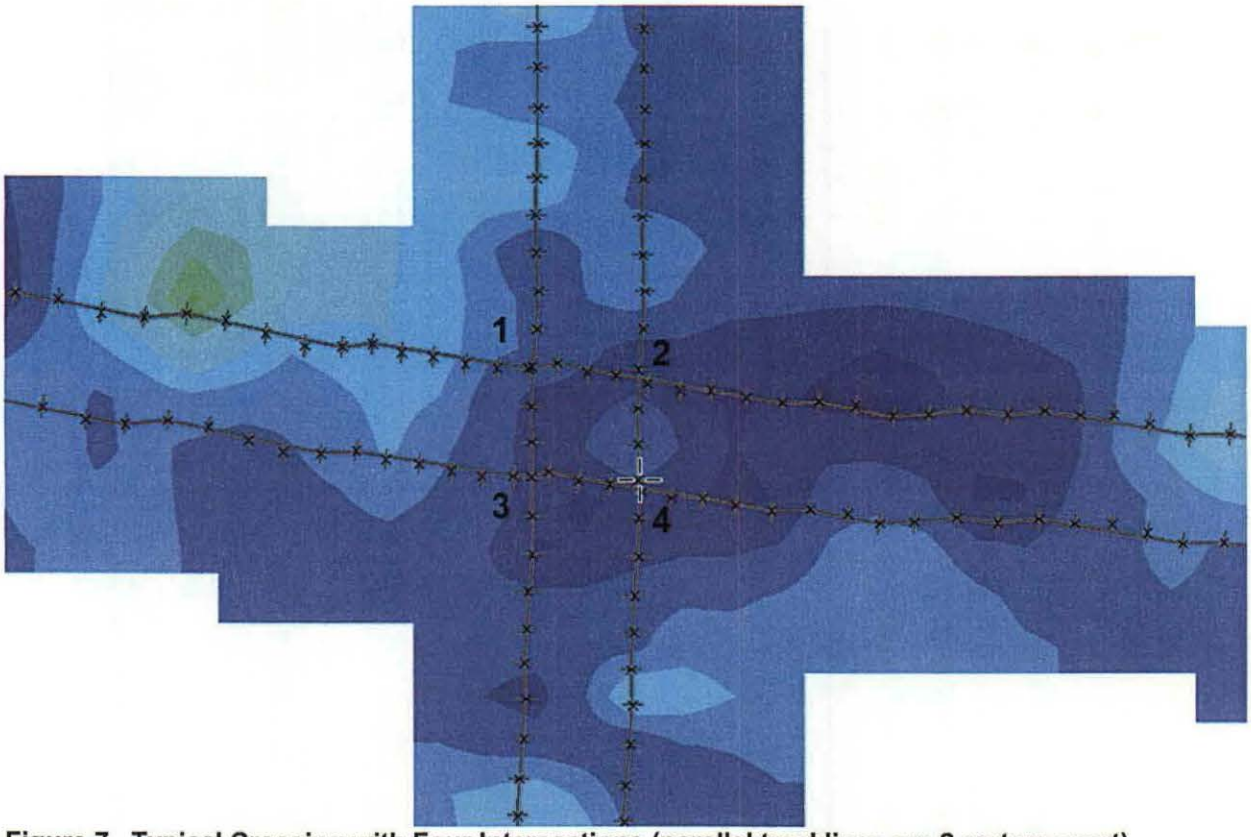


Figure 7. Typical Crossing with Four Intersections (parallel tracklines are 2 meters apart)

For all assessed crossing points, the average difference was always less then 1 nanoTesla (nT) and the average difference off all the crossing points assessed was 0.07nT, far below the noise threshold of 2nT. Cross-line analysis tables can be found in Appendix A.

Further analysis of cross lines was performed by differencing gridded data for all crossing points. A grid surface was created in Oasis Montaj for all cross lines and a separate grid was created for all main lines. The two grids were then differenced. The results were 6815 grid points with a mean difference of -0.05nT. Figure 8 summarizes these results with a histogram. It is apparent that the majority of points are within the noise levels of the MGA. In fact, 87% of all grid points are between -2 and 2nT. The data points that fall outside the noise threshold are likely the result of variable altitude, uncertainties that exist within the positioning data and artifacts of the minimum curvature gridding algorithm.

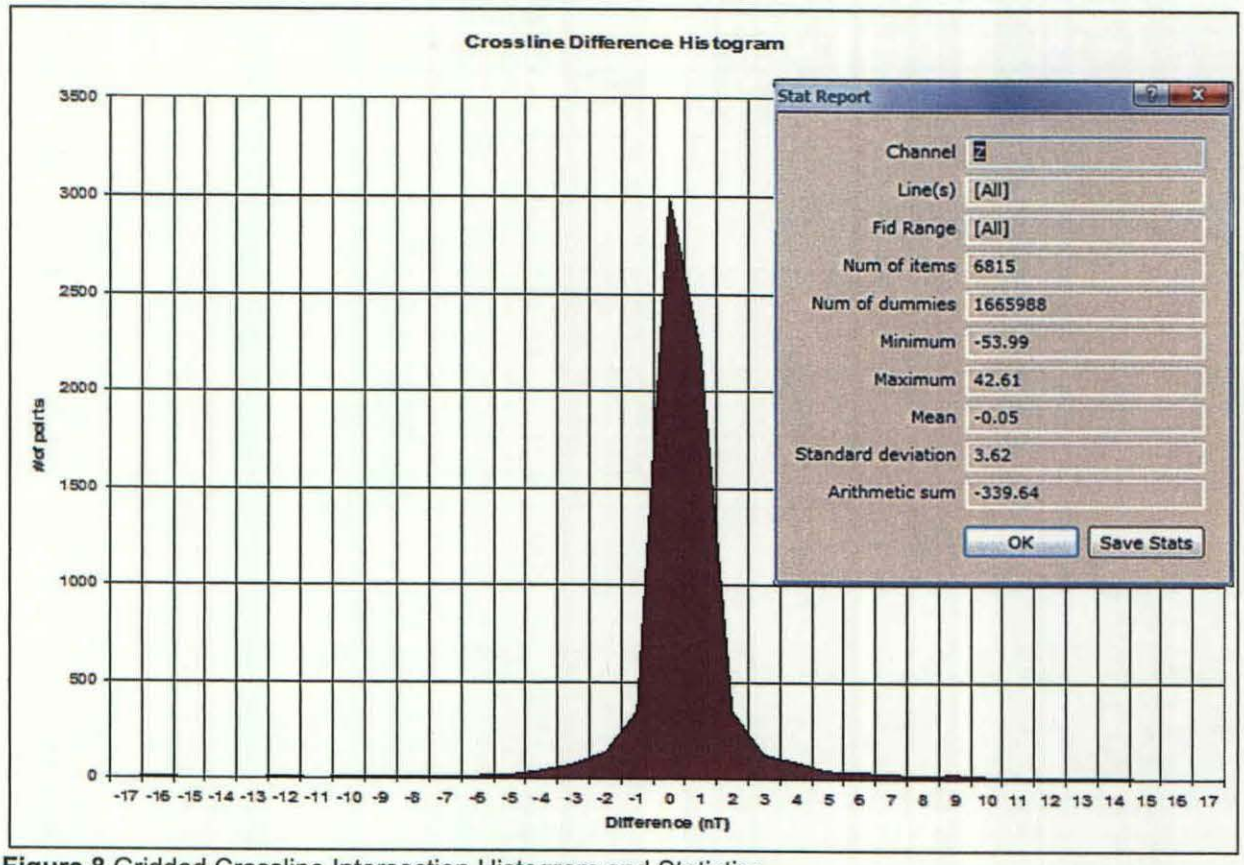


Figure 8 Gridded Crossline Intersection Histogram and Statistics.

Static Tests

To evaluate the functionality and sensitivity of the MGA a static test was performed each day that data were collected. The MGA was flown at a standard flight height of approximately 2m in an area found to be free of magnetic targets. Samples from each of the seven sensors were evaluated over a 1 to 3 min period to verify that the mean plus two times the standard deviation of the measurements was less that 2nT. Throughout the duration of the survey all sensors for all days passed the static test with the exception of sensor 3 on May 7th and 10th which had readings of 2.23 and 2.1 respectively (Table 1). These two readings are within 10% of the established threshold and are justifiably higher than the other sensor due to their closer proximity to the bottom. Sensors 3 and 6 are the bottom sensors and therefore have the highest average standard deviation of all the sensors due to their smaller standoff distance from the lake bed. Appendix B contains a static test summary statistics for each sensor for each day.

Table 1 – Static Test Results

		Sensors						
Date	**Line**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2-May	103-2257	0.89	0.63	0.85	0.65	0.59	0.8	0.59
3-May	104_1834	0.62	0.55	0.75	0.57	0.61	0.75	0.55
4-May	100_1529	0.51	0.55	0.72	0.53	0.51	0.7	0.53
5-May	101_1504	0.44	0.44	0.6	0.44	0.81	0.79	0.52
6-May	106_2135	0.88	0.86	1.08	0.86	0.84	1.08	0.84
7-May	030_1418	1.71	1.55	2.23	1.44	1.37	1.99	1.37
9-May	074_1455	0.73	0.69	1.03	0.71	0.71	0.99	0.68
10-May	055_2125	1.32	1.12	2.1	1.12	1.13	2	1.05
12-May	103_1749	0.86	0.98	1.12	0.84	0.8	1.02	0.71
13-May	061_2032	1.01	0.96	1.73	0.98	1.17	1.86	1.14
14-May	077_1957	0.81	1.01	1.43	0.91	1.16	1.85	1.08
15-May	103_1903	0.39	0.43	0.64	0.43	0.49	0.66	0.43
Average		0.86	0.91	1.33	1.04	1.17	1.58	1.27

Documentation of Systems Performance at Other Sites

The following is a series of examples of IVS surveys performed with the MGA both before and after operations at Naval Station Great Lakes (NSGL).

In 2006, Tetra Tech participated in the Underwater munitions potentially presenting an explosive hazard (MPPEH) Detection System Demonstration Program for the US Navy in Ostrich Bay, WA with the MGA. In this example five of the six items are detected, only the smallest item (a single fuze) was not detected (Figure 9). In this figure the Xs represent the positions of the seed items as determined by a Real Time Kinematic (RTK) Global Positioning System (GPS) and a weighted line guided by a diver.

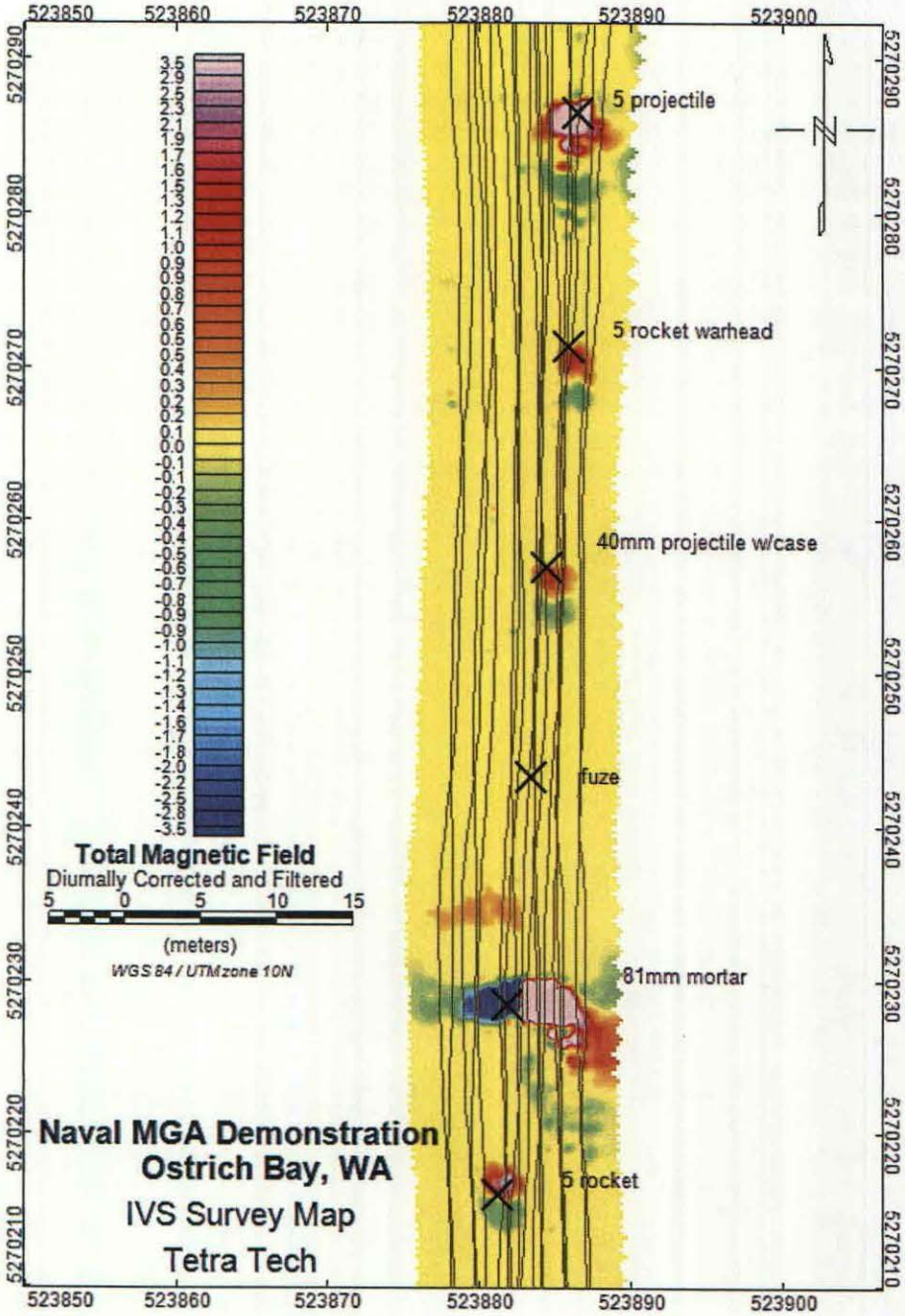


Figure 9. IVS survey in Ostrach Bay, WA, 2006

In the months following survey operations at NSGL the MGA was used on underwater MEC surveys at other sites. For these subsequent operations, the IVS was placed in more suitable locations and we were able to detect individual items accurately. For these surveys, the MGA and support sensor configuration was identical to that used for the NSGL survey. Figure 10 shows an example of detecting multiple small IVS items with the MGA.

ESTCP Wide Area Assessment Demonstration Site (Martha's Vineyard, MA)

In this example, we inspect the results of the IVS survey by looking at an individual pass with the gradiometer. Figure 10 shows the tracklines of multiple passes with the MGA over the IVS (thin gray lines) and the gridded data of the MGA's analytic signal. The track of the starboard array on line 506_1407 on June 28, 2010 is displayed in bold. The perpendicular ticks along this track denote the sample locations taken every 0.5 second. The array passes close to three of the IVS targets and has a measurable response to each. The along track magnetic response profile is shown in Figure 11. It is interesting to note that the maximum magnetic anomaly for the cluster of ten 20mm projectiles is less than that measured of the cluster of eight 20mm. This is likely the result of the proximity of the array to the target at the time of the measurement. This observation is also true for the single 40mm projectile with casing; one might expect this item to have a larger response than observed here. Regardless, all responses are far above the threshold value of 2nT. Note that a single full 20mm round was strongly detected, but that the cluster of four 20mm projectiles was not on this particular day. The same cluster of four 20mms was detected at the Patuxent River site on Aug 19, 2010, but not on August 14, 2010 (see Figure 12). These small items are detectable depending on site conditions.

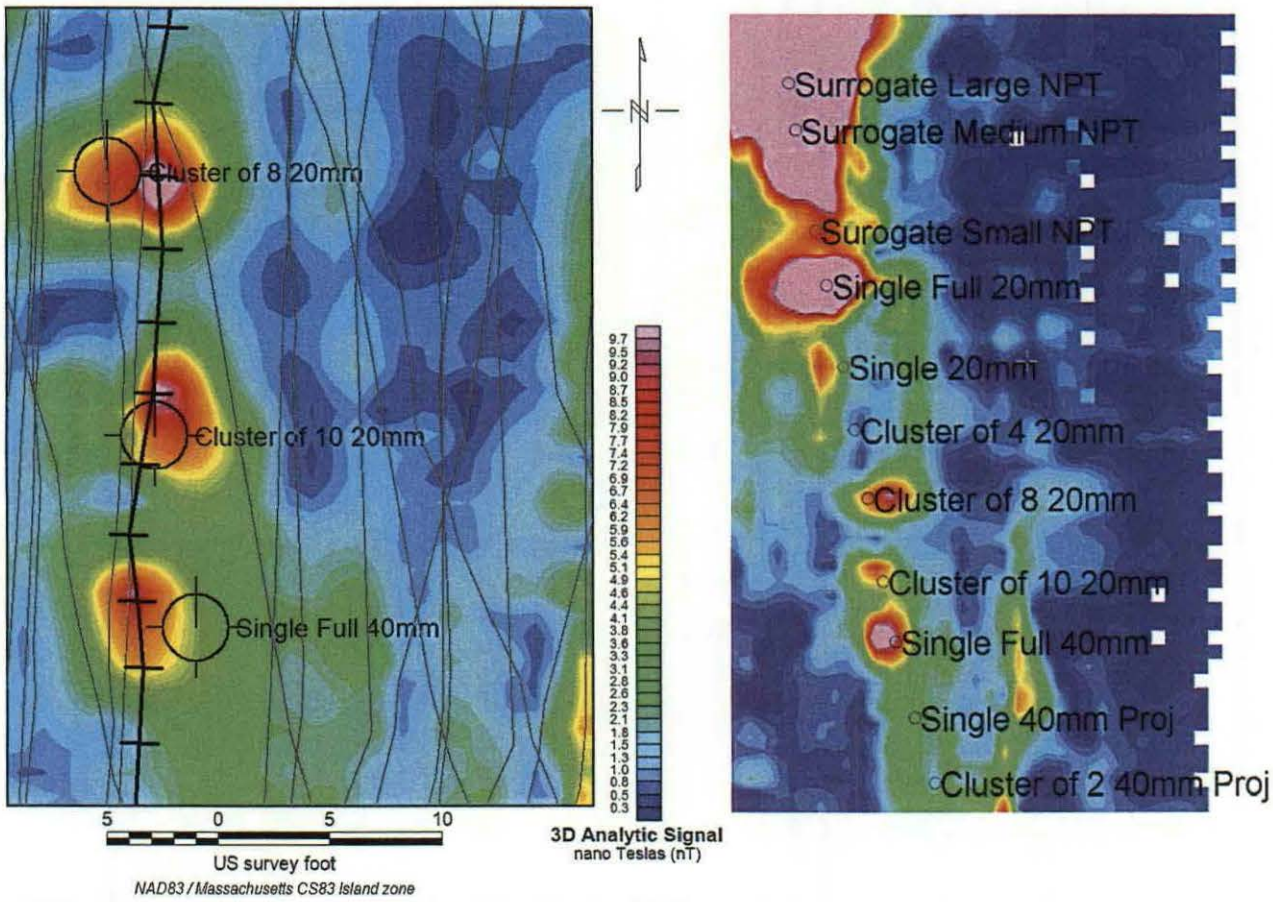


Figure 10 Examination of small IVS items with the MGA

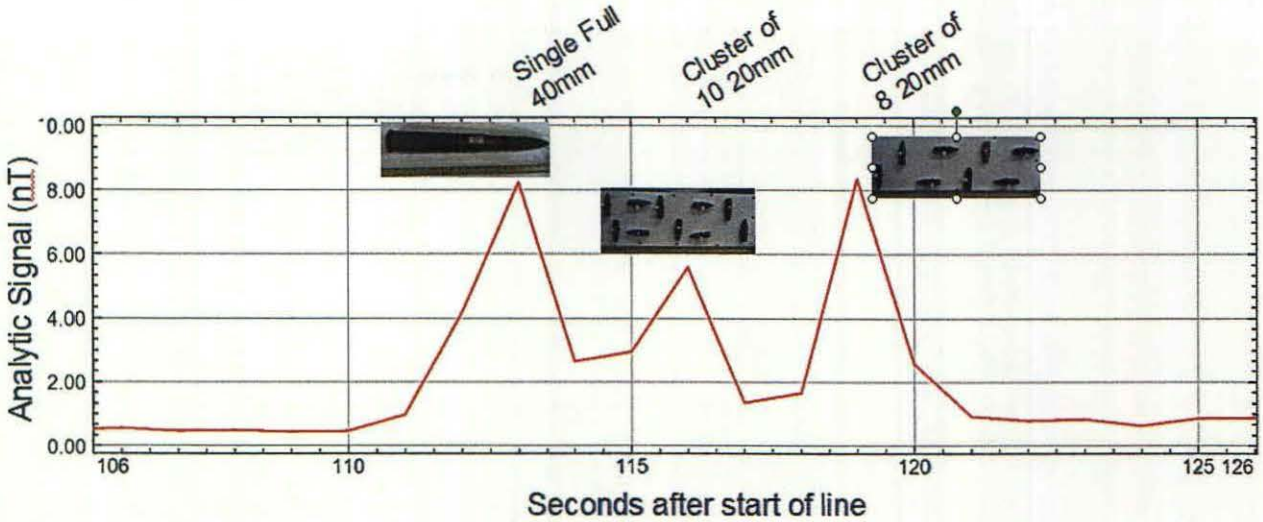
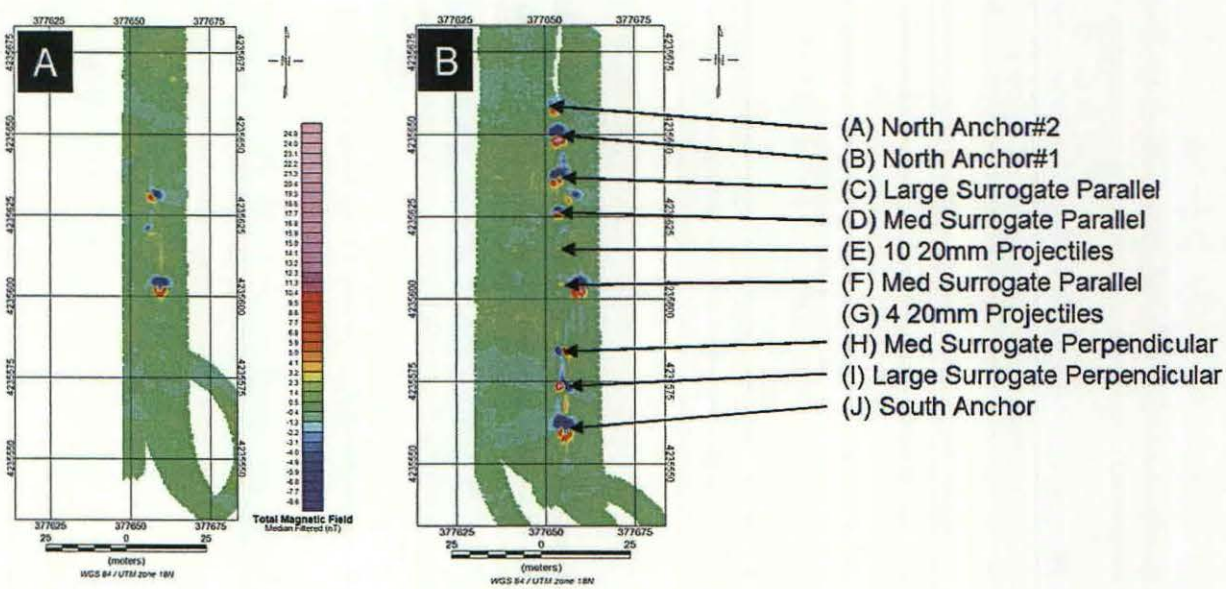


Figure 11. Profile of line 506_1406 past three small IVS items

Patuxent River Naval Air Station (Lexington Park, MD)

In August 2010, an additional munitions and explosives of concern (MEC) survey was performed at the Patuxent Naval Air Station with the MGA and a new IVS was constructed using some of the same items from NSGL IVS. Figure 12 shows a pre and post IVS deployment survey. All but the smallest of IVS items are detected with the MGA. In fact, Figure 13 shows how the orientation of the items can be derived from the dipole magnetic signal.



Pre IVS deployment survey. Note the three existing anomalies within the area.

MGA IVS survey on Aug 14th. Most of the deployed IVS items can be seen along with the three pre-existing items.

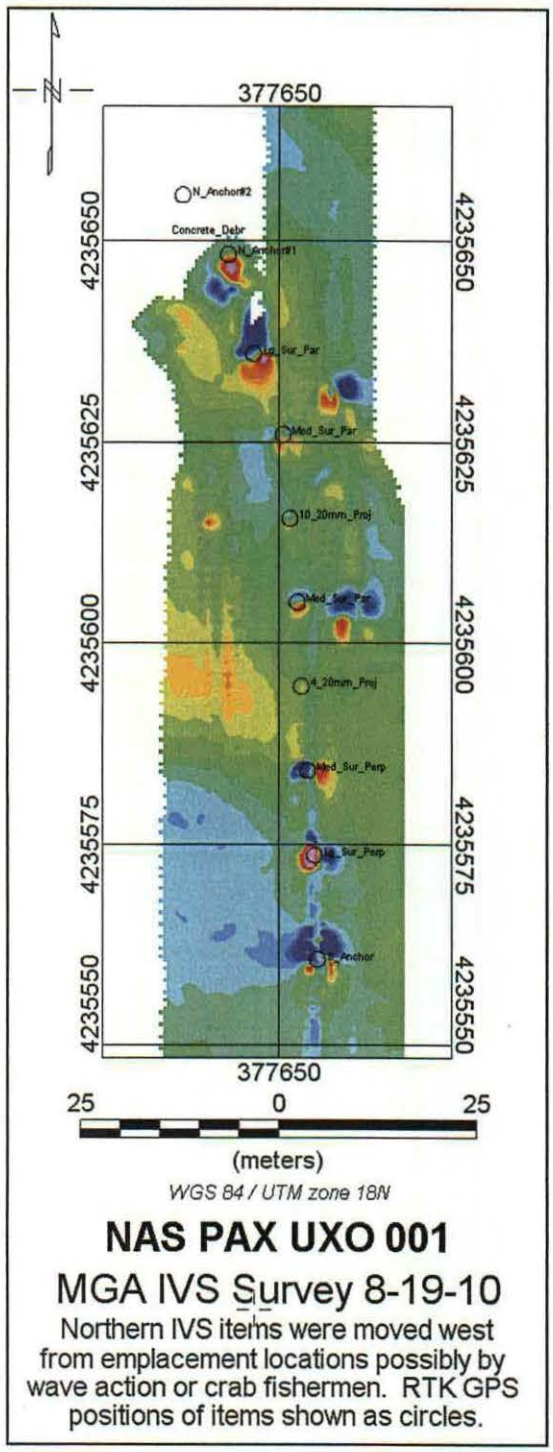
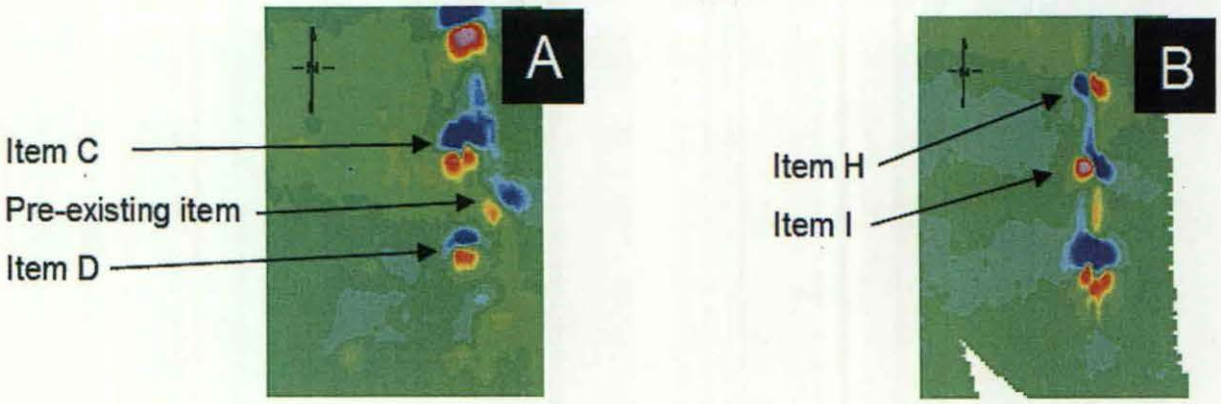


Figure 12. Detection of IVS items at Patuxent Naval Air Station with the MGA August 2010. Note cluster of four 20mm projectiles were detected on August 19, 2010 but not on August 14, 2010.



The orientation of the IVS items can also be derived from the MGA data. In Figure A the magnetic field of the "parallel" surrogates are oriented north-south. In Figure B the "perpendicular" surrogates are oriented east-west although they have opposite polarization. From this we see that the pre-existing item in Figure A has magnetic field orientation in the northeast-southwest direction suggesting that the item is elongated in that direction.

Figure 13. IVS items orientation determination with the MGA at Patuxent Naval Air Station.

Conclusions

The areas available within the Outer Harbor that had suitable water depths (10 to 20 feet) and enough buffer area for boat navigation were limited due to water depth, mooring blocks, docks, and the breakwater. The area selected for use was identified using MBE mapping, which mapped water depth and indicated that the area was free of debris above the harbor bottom (e.g. mooring blocks, shoals, rocks etc.). Once an area was identified using MBE mapping, a background geophysical survey using the MGA was conducted. This survey of the IVS area documented the presence of metal items within the area cleared by the multibeam. Due to the presence of metallic items in the area, it was not possible in all cases to discriminate individual IVS seed items from the surrounding metallic debris, which would have only been possible in an area free of background noise. However, the IVS test was run daily and QC tests confirmed positional accuracy, equipment functionality, repeatability of results, and the feasibility of detecting metallic objects in the harbor. Data collected with the MGA prior to and following the NTCGL survey provide additional documentation of the MGA performance and detection capabilities.

Appendix A

Cross Line Check

2-May

	Date	2-May	15-May	
	Line	103_2214	056_1957	Difference
Intersection	1	0.73	0.38	0.35
	2	1.42	1.8	-0.38
	3	1.5	1.5	0
	4	1.07	1.41	-0.34
	Average			**-0.0925**

May 3rd

	Date	3-May	5-May	
	Line	35_2249	106_2135	Difference
Intersection	1	0.63	1.08	-0.45
	2	0.38	0.73	-0.35
	3	0.27	0.32	-0.05
	4	0.87	0.33	0.54
	Average			**-0.0775**

	Date	3-May	3-May	
	Line	35_2249	105_2100	Difference
Intersection	1	0.37	0.29	0.08
	2	0.32	0.19	0.13
	3	0.59	0.22	0.37
	4	0.14	0.14	0
	Average			**0.145**

May 4th

	Date	4-May	15-May	
	Line	100_1529	081_1500	Difference
Intersection	1	0.31	0.25	0.06
	2	0.27	0.16	0.11
	3	0.26	0.2	0.06
	4	0.07	0.22	-0.15
	Average			**0.02**

May 5th

	Date	5-May	6-May	
	Line	101_1504	38_1528	Difference
Intersection	1	0.95	0.95	0
	2	0.27	0.47	-0.2
	3	0.22	0.37	-0.15
	4	0.93	0.37	0.56
	Average			**0.05**

	Date	5-May	5-May	
	Line	101_1504	84_1815	Difference
Intersection	1	0.29	0.44	-0.15
	2	0.28	0.95	-0.67
	3	0.19	0.5	-0.31
	4	0.22	0.66	-0.44
	Average			**-0.39**

May 6th

	Date	6-May	14-May	
	Line	106_2135	073_1821	Difference
Intersection	1	0.3	0.14	0.16
	2	0.4	0.44	-0.04
	3	0.64	0.25	0.39
	4	0.14	0.28	-0.14
	Average			**0.09**

	Date	6-May	6-May	
	Line	102_1730	80_1822	Difference
Intersection	1	0.47	0.35	0.12
	2	0.33	0.59	-0.26
	3	0.62	0.38	0.24
	4	0.9	0.28	0.62
	Average			**0.18**

May 7th

	Date	7-May	12-May	
	Line	100_1515	33_1610	Difference
Intersection	1	0.8	0.3	0.5
	2	0.27	0.09	0.18
	3	0.78	0.42	0.36
	4	0.87	0.29	0.58
	Average			**0.41**

	Date	7-May	7-May	
	Line	101_1616	30_1418	Difference
Intersection	1	0.39	0.61	-0.22
	2	0.36	0.25	0.11
	3	1.13	1.07	0.06
	4	0.78	0.57	0.21
	Average			**0.04**

9-May

	Date	9-May	3-May	
	Line	074_1455	105_2100	Difference
Intersection	1	0.71	0.34	0.37
	2	1	0.78	0.22
	3	0.41	0.44	-0.03
	4	0.59	1.41	-0.82
	Average			**-0.07**

10-May

	Date	10-May	3-May	
	Line	057_2140	105_2100	Difference
Intersection	1	0.27	0.91	-0.64
	2	0.33	1.51	-1.18
	3	0.52	0.56	-0.04
	4	0.25	0.54	-0.29
	Average			**-0.54**

12-May

	Date	12-May	7-May	
	Line	105_1831	24_1456	Difference
Intersection	1	1.51	1.24	0.27
	2	2.7	1.97	0.73
	3	1.2	0.97	0.23
	4	4.28	1.89	2.39
	Average			**0.91**

	Date	12-May	12-May	
	Line	104_1813	39_1644	Difference
Intersection	1	0.61	0.41	0.2
	2	0.75	0.46	0.29
	3	0.64	1.54	-0.9
	4	0.44	0.44	0
	Average			**-0.10**

13-May

	Date	13-May	3-May	
	Line	061_2032	105_2100	Difference
Intersection	1	0.52	0.63	-0.11
	2	1.24	1.26	-0.02
	3	4.22	2.06	2.16
	4	0.57	1.54	-0.97
	Average			**0.27**

14-May

	Date	14-May	3-May	
	Line	77_1957	105_2100	Difference
Intersection	1	0.38	0.69	-0.31
	2	0.29	0.6	-0.31
	3	0.5	0.44	0.06
	4	0.14	0.47	-0.33
	Average			**-0.22**

15-May

	Date	15-May	3-May	
	Line	083_1619	105_2100	Difference
Intersection	1	0.32	0.37	-0.05
	2	0.12	0.23	-0.11
	3	0.23	0.15	0.08
	4	0.09	0.34	-0.25
	Average			**-0.08**

	Date	15-May	15-May	
	Line	103_1903	85_1742	Difference
Intersection	1	0.44	0.15	0.29
	2	0.04	0.29	-0.25
	3	0.14	0.16	-0.02
	4	0.12	0.07	0.05
	Average			**0.02**

Appendix B

Appendix B.

Static Test May 2, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P103_2257_e_1
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-1.41
Maximum	2.28
Mean	0.01
Standard deviation	0.44
Arithmetic sum	3.25

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_2257_e_2
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-0.87
Maximum	0.90
Mean	0.01
Standard deviation	0.31
Arithmetic sum	2.20

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_2257_e_3
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-0.91
Maximum	1.68
Mean	0.01
Standard deviation	0.42
Arithmetic sum	2.54

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_2257_e_4
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-0.75
Maximum	0.95
Mean	0.01
Standard deviation	0.32
Arithmetic sum	2.45

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_2257_e_5
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-0.72
Maximum	0.92
Mean	0.01
Standard deviation	0.29
Arithmetic sum	1.88

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_2257_e_6
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-1.83
Maximum	0.97
Mean	0.00
Standard deviation	0.40
Arithmetic sum	1.33

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_2257_e_7
Fid Range	2000 to 2300
Num of items	301
Num of dummies	0
Minimum	-0.70
Maximum	0.89
Mean	0.01
Standard deviation	0.29
Arithmetic sum	2.12

OK | Save Stats

Static Test May 3, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P104_1834_e_1
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.74
Maximum	1.18
Mean	0.02
Standard deviation	0.30
Arithmetic sum	4.54

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P104_1834_e_2
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.82
Maximum	0.76
Mean	0.01
Standard deviation	0.27
Arithmetic sum	3.48

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P104_1834_e_3
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.90
Maximum	1.25
Mean	0.01
Standard deviation	0.37
Arithmetic sum	3.91

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P104_1834_e_4
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.68
Maximum	1.14
Mean	0.01
Standard deviation	0.28
Arithmetic sum	3.53

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S104_1834_e_5
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.97
Maximum	0.72
Mean	0.01
Standard deviation	0.30
Arithmetic sum	3.54

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S104_1834_e_6
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-1.59
Maximum	0.75
Mean	0.01
Standard deviation	0.37
Arithmetic sum	2.95

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S104_1834_e_7
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.75
Maximum	0.80
Mean	0.01
Standard deviation	0.27
Arithmetic sum	3.60

OK | Save Stats

Static Test May 4, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P100_1529_e_1
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.86
Maximum	0.54
Mean	-0.01
Standard deviation	0.26
Arithmetic sum	-2.56

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P100_1529_e_2
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.81
Maximum	0.80
Mean	-0.01
Standard deviation	0.28
Arithmetic sum	-3.98

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P100_1529_e_3
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-1.06
Maximum	0.95
Mean	-0.02
Standard deviation	0.37
Arithmetic sum	-5.38

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P100_1529_e_4
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.80
Maximum	0.63
Mean	-0.01
Standard deviation	0.27
Arithmetic sum	-3.01

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S100_1529_e_5
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.64
Maximum	0.86
Mean	-0.01
Standard deviation	0.26
Arithmetic sum	-2.20

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S100_1529_e_6
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-1.11
Maximum	1.25
Mean	-0.02
Standard deviation	0.36
Arithmetic sum	-5.09

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S100_1529_e_7
Fid Range	10000 to 10300
Num of items	301
Num of dummies	0
Minimum	-0.72
Maximum	0.74
Mean	-0.01
Standard deviation	0.27
Arithmetic sum	-3.74

OK | Save Stats

Static Test May 5, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P101_1504_e_1
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-0.61
Maximum	0.52
Mean	-0.00
Standard deviation	0.22
Arithmetic sum	-0.84

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P101_1504_e_2
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-0.58
Maximum	0.47
Mean	0.00
Standard deviation	0.22
Arithmetic sum	0.47

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P101_1504_e_3
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-1.00
Maximum	0.78
Mean	-0.00
Standard deviation	0.30
Arithmetic sum	-0.45

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P101_1504_e_4
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-0.61
Maximum	0.49
Mean	-0.00
Standard deviation	0.22
Arithmetic sum	-0.49

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S101_1504_e_5
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-3.03
Maximum	1.24
Mean	0.01
Standard deviation	0.40
Arithmetic sum	1.83

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S101_1504_e_6
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-1.04
Maximum	1.84
Mean	0.01
Standard deviation	0.39
Arithmetic sum	2.26

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S101_1504_e_7
Fid Range	7500 to 7800
Num of items	301
Num of dummies	0
Minimum	-0.95
Maximum	1.03
Mean	0.00
Standard deviation	0.26
Arithmetic sum	0.98

OK | Save Stats

Static Test May 6, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P106_2135_1
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-1.30
Maximum	1.33
Mean	-0.00
Standard deviation	0.44
Arithmetic sum	-0.73

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P106_2135_2
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-1.11
Maximum	1.26
Mean	-0.00
Standard deviation	0.43
Arithmetic sum	-0.26

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P106_2135_3
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-1.36
Maximum	1.51
Mean	-0.00
Standard deviation	0.54
Arithmetic sum	-1.34

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P106_2135_4
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-1.20
Maximum	1.22
Mean	0.00
Standard deviation	0.43
Arithmetic sum	0.27

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S106_2135_5
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-0.91
Maximum	1.26
Mean	0.01
Standard deviation	0.42
Arithmetic sum	1.58

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S106_2135_6
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-1.09
Maximum	1.62
Mean	-0.00
Standard deviation	0.54
Arithmetic sum	-0.18

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S106_2135_7
Fid Range	0 to 300
Num of items	301
Num of dummies	0
Minimum	-0.98
Maximum	1.37
Mean	0.00
Standard deviation	0.42
Arithmetic sum	0.93

OK | Save Stats

Static Test May 7, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P030_1418_e_1
Fid Range	700 to 1050
Num of items	351
Num of dummies	0
Minimum	-2.92
Maximum	4.49
Mean	0.01
Standard deviation	0.85
Arithmetic sum	4.26

OK | Save Stats

Stat Report

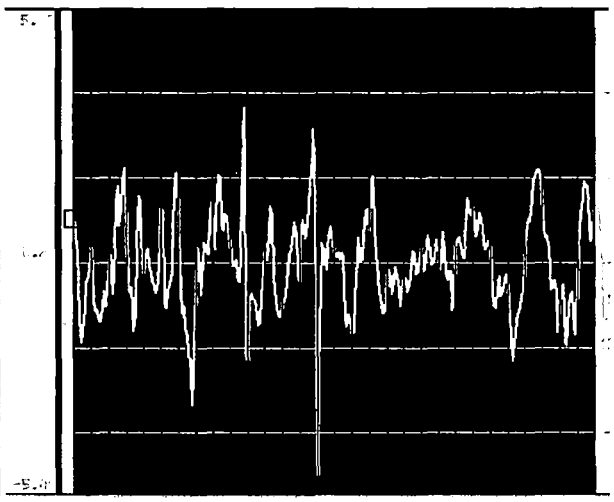
Channel	TF_Filt
Line(s)	P030_1418_e_2
Fid Range	700 to 1050
Num of items	351
Num of dummies	0
Minimum	-2.04
Maximum	4.02
Mean	0.01
Standard deviation	0.77
Arithmetic sum	4.42

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P030_1418_e_3
Fid Range	750 to 1050
Num of items	301
Num of dummies	0
Minimum	-5.01
Maximum	3.66
Mean	-0.01
Standard deviation	1.12
Arithmetic sum	-3.37

OK | Save Stats



Stat Report

Channel	TF_Filt
Line(s)	P030_1418_e_4
Fid Range	750 to 1050
Num of items	301
Num of dummies	0
Minimum	-2.02
Maximum	1.93
Mean	-0.02
Standard deviation	0.73
Arithmetic sum	-5.84

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S030_1418_e_6
Fid Range	750 to 1050
Num of items	301
Num of dummies	0
Minimum	-3.34
Maximum	5.55
Mean	-0.03
Standard deviation	1.04
Arithmetic sum	-8.19

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S030_1418_e_5
Fid Range	750 to 1050
Num of items	301
Num of dummies	0
Minimum	-1.89
Maximum	1.95
Mean	-0.03
Standard deviation	0.70
Arithmetic sum	-8.47

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S030_1418_e_7
Fid Range	750 to 1050
Num of items	301
Num of dummies	0
Minimum	-1.75
Maximum	1.91
Mean	-0.03
Standard deviation	0.70
Arithmetic sum	-8.78

OK | Save Stats

Static Test May 9, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P074_1455_e_1
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-0.87
Maximum	1.01
Mean	-0.01
Standard deviation	0.37
Arithmetic sum	-3.72

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P074_1455_e_2
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-0.78
Maximum	0.92
Mean	-0.01
Standard deviation	0.35
Arithmetic sum	-3.88

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P074_1455_e_3
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-1.55
Maximum	1.27
Mean	-0.01
Standard deviation	0.52
Arithmetic sum	-3.22

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P074_1455_e_4
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-0.73
Maximum	0.97
Mean	-0.01
Standard deviation	0.36
Arithmetic sum	-4.30

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S074_1455_e_5
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-0.82
Maximum	1.24
Mean	-0.01
Standard deviation	0.36
Arithmetic sum	-4.34

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S074_1455_e_6
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-1.16
Maximum	1.43
Mean	-0.01
Standard deviation	0.50
Arithmetic sum	-2.94

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S074_1455_e_7
Fid Range	4550 to 4850
Num of items	301
Num of dummies	0
Minimum	-0.83
Maximum	0.92
Mean	-0.02
Standard deviation	0.35
Arithmetic sum	-4.82

OK | Save Stats

Static Test May 10, 2010. Sensors 1 through 7

Stat Report

Channel	TF Filt
Line(s)	P055_2125_e_1
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-2.46
Maximum	2.12
Mean	0.05
Standard deviation	0.64
Arithmetic sum	6.31

OK | Save Stats

Stat Report

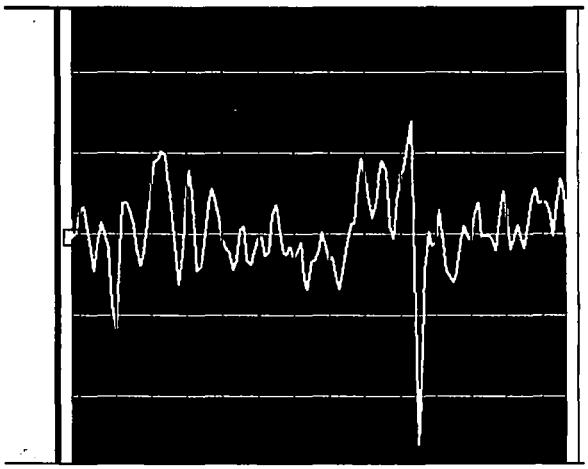
Channel	TF Filt
Line(s)	P055_2125_e_2
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-1.05
Maximum	1.36
Mean	0.08
Standard deviation	0.52
Arithmetic sum	11.31

OK | Save Stats

Stat Report

Channel	TF Filt
Line(s)	P055_2125_e_3
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-5.19
Maximum	2.79
Mean	0.07
Standard deviation	1.03
Arithmetic sum	9.14

OK | Save Stats



Stat Report

Channel	TF_Filt
Line(s)	P055_2125_e_4
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-1.56
Maximum	1.38
Mean	0.06
Standard deviation	0.53
Arithmetic sum	8.53

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S055_2125_e_5
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-0.96
Maximum	2.29
Mean	0.07
Standard deviation	0.54
Arithmetic sum	10.06

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S055_2125_e_6
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-1.93
Maximum	2.35
Mean	0.12
Standard deviation	0.94
Arithmetic sum	17.13

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S055_2125_e_7
Fid Range	288 to 427
Num of items	140
Num of dummies	0
Minimum	-1.05
Maximum	1.14
Mean	0.07
Standard deviation	0.49
Arithmetic sum	9.98

OK | Save Stats

Static Test May 12, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P103_1749_1
Fid Range	1100 to 1400
Num of items	301
Num of dummies	0
Minimum	-1.23
Maximum	1.06
Mean	-0.02
Standard deviation	0.44
Arithmetic sum	-6.57

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1749_2
Fid Range	1100 to 1400
Num of items	301
Num of dummies	0
Minimum	-1.21
Maximum	2.80
Mean	-0.02
Standard deviation	0.50
Arithmetic sum	-5.48

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1749_3
Fid Range	1100 to 1400
Num of items	301
Num of dummies	0
Minimum	-1.75
Maximum	1.37
Mean	-0.02
Standard deviation	0.57
Arithmetic sum	-6.30

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1749_4
Fid Range	1100 to 1400
Num of items	301
Num of dummies	0
Minimum	-1.16
Maximum	1.24
Mean	-0.02
Standard deviation	0.43
Arithmetic sum	-6.79

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1749_5
Fid Range	1250 to 1550
Num of items	301
Num of dummies	0
Minimum	-1.22
Maximum	1.40
Mean	-0.00
Standard deviation	0.40
Arithmetic sum	-1.03

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1749_6
Fid Range	1250 to 1550
Num of items	301
Num of dummies	0
Minimum	-1.68
Maximum	1.59
Mean	0.00
Standard deviation	0.51
Arithmetic sum	0.95

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1749_7
Fid Range	1250 to 1550
Num of items	301
Num of dummies	0
Minimum	-1.24
Maximum	1.11
Mean	0.01
Standard deviation	0.35
Arithmetic sum	1.82

OK | Save Stats

Static Test May 13, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P061_2032_1
Fid Range	400 to 700
Num of items	301
Num of dummies	0
Minimum	-1.06
Maximum	1.42
Mean	0.01
Standard deviation	0.50
Arithmetic sum	2.49

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P061_2032_2
Fid Range	400 to 700
Num of items	301
Num of dummies	0
Minimum	-1.01
Maximum	1.64
Mean	0.00
Standard deviation	0.48
Arithmetic sum	0.46

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P061_2032_3
Fid Range	400 to 700
Num of items	301
Num of dummies	0
Minimum	-2.11
Maximum	2.79
Mean	0.01
Standard deviation	0.86
Arithmetic sum	4.00

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P061_2032_4
Fid Range	400 to 700
Num of items	301
Num of dummies	0
Minimum	-0.98
Maximum	1.64
Mean	-0.00
Standard deviation	0.49
Arithmetic sum	-0.04

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S061_2032_5
Fid Range	3725 to 3875
Num of items	151
Num of dummies	0
Minimum	-1.00
Maximum	1.31
Mean	0.05
Standard deviation	0.56
Arithmetic sum	7.52

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S061_2032_6
Fid Range	3725 to 3875
Num of items	151
Num of dummies	0
Minimum	-2.05
Maximum	2.34
Mean	0.04
Standard deviation	0.91
Arithmetic sum	6.29

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S061_2032_7
Fid Range	3725 to 3875
Num of items	151
Num of dummies	0
Minimum	-1.12
Maximum	1.27
Mean	0.02
Standard deviation	0.56
Arithmetic sum	3.23

OK | Save Stats

Static Test May 14, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P077_1957_1
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-0.91
Maximum	1.05
Mean	0.01
Standard deviation	0.40
Arithmetic sum	2.81

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P077_1957_2
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-1.78
Maximum	1.19
Mean	0.01
Standard deviation	0.50
Arithmetic sum	3.30

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P077_1957_3
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-1.97
Maximum	1.92
Mean	0.01
Standard deviation	0.71
Arithmetic sum	3.58

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P077_1957_4
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-1.17
Maximum	1.17
Mean	0.01
Standard deviation	0.45
Arithmetic sum	3.28

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S077_1957_5
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-1.99
Maximum	1.72
Mean	0.02
Standard deviation	0.57
Arithmetic sum	5.02

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S077_1957_6
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-3.35
Maximum	2.80
Mean	0.01
Standard deviation	0.92
Arithmetic sum	3.52

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S077_1957_7
Fid Range	2500 to 2800
Num of items	301
Num of dummies	0
Minimum	-1.92
Maximum	1.51
Mean	0.01
Standard deviation	0.54
Arithmetic sum	4.33

OK | Save Stats

Static Test May 15, 2010. Sensors 1 through 7

Stat Report

Channel	TF_Filt
Line(s)	P103_1903_e_1
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.67
Maximum	0.42
Mean	-0.01
Standard deviation	0.20
Arithmetic sum	-3.91

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1903_e_2
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.60
Maximum	0.57
Mean	-0.01
Standard deviation	0.22
Arithmetic sum	-4.01

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1903_e_3
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-1.02
Maximum	0.92
Mean	-0.02
Standard deviation	0.33
Arithmetic sum	-4.76

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	P103_1903_e_4
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.63
Maximum	0.57
Mean	-0.01
Standard deviation	0.22
Arithmetic sum	-4.48

OK Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1903_e_5
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.62
Maximum	0.63
Mean	-0.01
Standard deviation	0.25
Arithmetic sum	-3.32

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1903_e_6
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.99
Maximum	1.41
Mean	-0.02
Standard deviation	0.34
Arithmetic sum	-4.92

OK | Save Stats

Stat Report

Channel	TF_Filt
Line(s)	S103_1903_e_7
Fid Range	450 to 750
Num of items	301
Num of dummies	0
Minimum	-0.47
Maximum	0.44
Mean	-0.01
Standard deviation	0.22
Arithmetic sum	-4.45

OK | Save Stats