FINAL REPORT

UXO Detection and Characterization in the Marine Environment

ESTCP Project MM-0324

November 2008

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Environmental Security Technology Certification Program

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 NOV 2008	**N/A**	**-**

4. TITLE AND SUBTITLE **UXO Detection and Characterization in the Marine Environment**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Science Applications International Corporation 120 Quade Dr. Cary, NC 27513**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**76**	

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LIST OF ACRONYMS

Acronym	Explaination		Acronym	Explaination
ACE	Army Corps of Engineers		Mb	megabyte
AO	Abandoned Ordnance		MEC	Munitions and Explosives of Concern
ASR	Archives Search Report		MHz	megahertz
BBS	Below Bottom Surface		MLLW	Mean Lower Low Water
BDU	Bomb Demonstration Unit		MTA	Marine Towed Array
BRAC	Base Realignment and Closure		MTADS	Multi-sensor Towed Array Detection System
CAD	Computer Assisted Design		montaj	Trademark copyrighted by Geosoft
Cal	Caliber		NAD	Naval Ammunition Depot
C&P	Cost and Performance		NAD	North American Datum
Cs	Cesium		NAVFAC	Naval Facilities Command
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act		NEODTD	Naval Explosives Ordnance Detection Technology Division
COTS	Commercial, Off the Shelf		NOSSA	Naval Ordnance Safety and Security Activity
CTT	Closed, Transferred, and Transferring		NSWC	Naval Surface Warfare Center
DAQ	Data Acquisition System		nT	Nano Tesla
DAS	Data Analysis System		OSHA	Occupational Safety & Health Administration
DGPS	Digital Global Positioning System		OU	Operational Unit
DMM	Discarded Military Munitions		PA/SI	Preliminary Assessment/Site Inspection
DoD	Department of Defense		PCB	Printed Circuit Board
EE/CA	Engineering Evaluation/Cost Analysis		POS	Prove-Out-Site = GPO
EFA-NW	Environmental Field Activity-Northwest		PVC	Poly-vinylchloride
EMI	Electromagnetic Induction		QA	Quality Assurance
EOD	Explosive Ordnance Disposal		QC	Quality Control
EOTI	Explosive Ordnance Technology, Inc.		RI/FS	Remedial Investigation/Feasibility Study
EPA	Environmental Protection Agency		ROD	Record of Decision
ERDC	Engineer Research & Development Center		RTK	Real-time Kinetic
ESTCP	Environmental Security Technology Certification Program		SCI	Structural Composites Inc.
FUDS	Formerly Used Defense Site		SERDP	Strategic Environmental Research and Detection Program
GPO	Geophysical Prove-Out = POS		S/N	Signal-To-Noise
GPS	Global Positioning System		SUV	Sports Utility Vehicle
GUI	Graphic User Interface		TCRA	Time-Critical Removal Action
HAE	Height Above Ellipsoid		USACE	US Army Corps of Engineers
HE	High Explosive		USGS	US Geological Survey
Hz	Hertz		UTM	Universal Transverse Mecator
IMU	Inertial Measurement Unit		UXO	Unexploded Ordnance
JPHC/NHB	Jackson Park Housing Complex/Naval Hospital Bremerton		VCT	Vehicle Control Technologies, Inc.
Kt	1 Nautical Mile/hr = 1 kt		WH	Warhead
lb	pound		WP	Work Plan

EXECUTIVE SUMMARY

The second demonstration of the Marine Towed Array took place June 12-30, 2006 on Ostrich Bay (Puget Sound) in the state of Washington. This Bay is adjacent to the former NAD Puget Sound, which for 50 years operated as an ordnance manufacturing and storage facility to supply Naval vessels operating from the West Coast. MEC and munitions components were on-loaded and off-loaded between three piers and lighters (powered barges) as part of the NAD operations. The facility was decommissioned in 1959; subsequently 3 of the 4 piers have been removed. In the 1980s several thousand pounds of intact DMM were removed from the immediate vicinity of Pier II, which still remains standing. For the past 10 years DMM clean up operations have been ongoing, mostly on the land that originally composed the NAD. The NAD has subsequently been replaced with a high density Naval housing community and a hospital, the Naval Hospital – Bremerton.

NAVFAC, working in cooperation with EPA, Region 10 is preparing to extend the cleanup activities into Ostrich Bay. In preparation for these activities, NAVFAC Northwest has constructed an ordnance Prove-Out-Site along the east side of the Bay in a 50 X 200 meter area to evaluate various survey technologies for use in characterizing ordnance contamination in the Bay. SAIC demonstrated the MTA during June 2006, first surveying the POS and presenting the analyzed data to NAVFAC for evaluation.

Following this, the MTA was used to conduct a blanket survey of all regions of the Bay thought likely to contain DMM. Operations concentrated along the western shore where the 4 piers were located that originally served the NAD. The areas around the current Pier II were incompletely surveyed because of the very steep-walled dredge cuts that remain around the Pier. Areas in the vicinity of the former Pier I, the former Railroad Pier, and the Current Pier II remain very highly contaminated with both large and small metallic anomalies.

About 220 acres of the Bay (about 75% of the total area) were surveyed with the MTA, all data were analyzed, and target lists, with recommended targets for investigation were submitted to NAVFAC. NAVFAC, working with NEODTD and the Bangor Naval EOD Detachment dove on and characterized 108 selected targets from all regions of the Bay. Eight targets were confirmed to be DMM or DMM components. Seven of the eight DMM targets were recovered in the immediate vicinity of the former Pier I, one DMM target was recovered in the vicinity of the former Railroad Pier.

To eventually cleanup DMM from the Bay will require an initial surface cleanup of the areas under and adjacent to Pier I, Pier II, and the Railroad Pier and a resurvey of these relatively small areas to be followed by target reacquisition and recovery. The areas immediately adjacent to Pier I and the Railroad Pier may require multiple resurvey and cleanup cycles to confidently remove all DMM-related materials.

In this report we describe the MTA survey activities from June 2006, our data analyses, the survey products that supported the intrusive investigations, and our analysis of the results of the intrusive investigation results.

1.0 INTRODUCTION

1.1. Background

1.1.1 UXO in the Marine Environment: As a result of past military training and weapons-testing activities, Unexploded Ordnance (UXO) is present at sites designated for Base Realignment And Closure (BRAC) and at Formerly Used Defense Sites (FUDS). Many of these sites associated with military practice and test ranges contain significant land areas with a marine component. Others are associated with ordnance manufacturing and/or assembly sites, storage depots and distribution sites, or storage areas associated with training operations. The first type of sites is typically associated with dispersed ordnance (inert and training rounds and ordnance duds. The depot and storage sites are typically characterized by Discarded Military Munitions (DMM). Although it is known that between 10 and 20 million acres of dry land UXO contamination are associated with Closed, Transferred, and Transferring (CTT) ranges, the fraction of this area that is underwater and inaccessible to standard UXO search technologies is poorly defined; however, it likely exceeds a million acres. The marine environment presents a complex challenge for UXO search technologies, because it includes wetlands, fresh water ponds and lakes, estuaries, rivers, coastal bays, tidal flats, and ocean shores, including shallow water coral reefs.

Although much of the marine UXO contamination has resulted from overshoots of land ranges, off-shore areas also have been used as ranges. Furthermore, we must acknowledge that historically it was common to dispose of excess or unwanted munitions (often resulting from land clearances) by simply dumping the materials into an adjacent body of water. This is evident in many areas by simple inspection of the shoreline adjacent to target and practice ranges. In addition to UXO challenges associated specifically with ranges, there exist significant examples of UXO contamination associated with dredging and beach replenishment operations, as well as confined areas associated with Naval Bases and ammunition manufacturing and shipping operations that have potential or known underwater DMM contamination.

At the time of this demonstration there were no proven automated technologies for conducting UXO geophysical surveys that result in documented mapped data files showing the extent, densities, and types of ordnance contamination for the underwater environment. The application of automated survey technologies has become routine on land-based ranges using hand-held, man-portable, vehicular-towed, or airborne sensor arrays coupled to GPS (or other types of) navigation systems for precise location positioning. Underwater UXO searches are typically conducted by divers using hand-held magnetometers. Discovered targets are either prosecuted as they are found or they are marked with weights and floats for later prosecution.

1.1.2 The Environmental Problem: The second demonstration of the Marine Towed Array (MTA) was on Ostrich Bay adjacent to the current Jackson Park Housing Complex and the Naval Hospital Bremerton. This area has an ordnance history stretching back more than 100 years. The "Archive Search Report," published in 2002 succinctly describes the site evolution.[1] The Naval Ammunition Depot was established in 1904 and decommissioned in 1959. The Depot served as a manufacturing, assembly point, storage depot for Naval Ordnance during its entire history. Component materials and chemicals were off loaded at three piers in Ostrich Bay from lighters and finished ammunition was reloaded onto the shallow water barges for transport to deep water where it was subsequently loaded onto Naval ships. There is a long history of both chemical and UXO contamination on land areas associated with the Depot and by DMM contamination in the Bay associated with loading operations at the piers. Both the former NAD Puget Sound mainland areas and the associated areas in Ostrich Bay have become of concern with the State and Federal Environmental Agencies, the Native Tribes of the area, and other stakeholders.

1.1.3 The MTA Technology: This report describes the deployment of the MTA to conduct a comprehensive DMM survey of Ostrich Bay to map out the potential UXO contamination problem associated with 55 years of operations at the marine piers. The MTA survey was designed to produce electronic displays of the magnetometry and EMI surveys of the Bay, lists of analyzed magnetic anomalies discovered in the Bay, and a suggested list of anomalies recommended for intrusive examination. This demonstration follows the first demonstration of the MTA on the Currituck Sound offshore from the former Duck Naval Bombing Range.[2]

1.2 Objective of the Demonstration

Our objective for this demonstration was to conduct an efficient and high-quality marine ordnance survey of Ostrich Bay. Our demonstration began with a survey and analysis of a marine Prove-Out-Site prepared by NAVFAC on the eastern shore of the Bay and concluded with a comprehensive survey of much of the remainder of the Bay. We expected that geophysical marine surveys would be conducted by other commercial firms before any MEC recovery operations were undertaken. These additional surveys allowed the MTA system performance to be evaluated against other developing technologies.

1.3 Regulatory Drivers

The regulatory issues affecting the UXO problem are most frequently associated with the BRAC and FUDS processes involving the transfer of DoD property to other agencies or to the civilian sector. When transfer of responsibility to other government agencies or to the civilian sector takes place, the DoD lands fall under the compliance requirements of the Superfund statutes. Section 2908 of the 1993 Public Law 103-160 requires adherence to CERCLA provisions. The basic issues center upon the assumption of liability for ordnance contamination on the previously DoD-controlled sites.

MEC operations at the Jackson Park Housing Complex and the Naval Hospital Bremerton have been and continue to be conducted under CERCLA site guidelines. The areas on shore fall within Operable Units OU 1 and OU 3T (terrestrial). The offshore areas adjacent to the JPHC/NHB are a part of OU 3M (Marine). OU 3M includes the approximate 79 acres of Navy property between the 0 feet Mean Lower Low Water (MLLW) line and the 4 fathom line in Ostrich Bay, and additionally include areas of Ostrich Bay that have munitions contamination beyond the Navy property line.[3]

The lands under Ostrich Bay beyond the Navy property line are the responsibility of the State of Washington. To our knowledge all operations involving OU-3M have involved NAVFAC EFANW, US EPA (Region 10), Washington State Department of Natural Resources, and the Washington State Biologist.[4]

In addition to the stakeholder interests that are represented by the regulators and agencies, a representative of the Suquamish Tribe was involved in all correspondence involving OU 3M operations. Homeowners, property owners, and recreational users of the bay are represented by various citizen and homeowners groups that surround the Bay. These groups have been officially informed of significant activities involved in OU 3M operations, and they are actively involved *via* Email exchanges with various government agencies associated with these operations.

In association with the installation of the POS, and likely survey operations that were conducted on the site (and other areas of Ostrich Bay) a "Biological Evaluation of the Jackson Park Navy Housing Area Ostrich Bay Geophysical Test Site," was developed by the senior Natural Resources Specialist at NAVFAC EFA-NW. In this study the likely effects on threatened and endangered marine species of the sound and radiation-emitting instruments and the physical activities that will be conducted on the Bay are evaluated. Species included are the Chinook salmon, the Steller Sea Lion, the Leatherback Sea Turtle, the Humpback Whale, the Southern Killer Whale, the Bull Trout, and the Bald Eagle.[4]

2.0 TECHNOLOGY

2.1 Technology Description

The MTA technology consists of the fielded hardware and software for data acquisition, Figure 1, the software tools specifically adapted for data processing and preparation of the data for analysis, and the specific software suites for carrying out analysis of the magnetic anomalies, characterizing and classifying their signatures, and preparation of the various graphics and spreadsheet products to support subsequent target reacquisition and intrusive investigations, and the preparation of demonstration reports.

Figure 1. The 30 ft pontoon boat is shown towing the sensor platform during a survey on Ostrich Bay. The sensor platform is submerged about 7 ft below the surface.

For the tow vessel, we chose a 30-foot long triple pontoon boat manufactured by Crest, Figure 2. This is the maximum width boat that can be transported over the road without special wide load permits. A 175-horsepower outboard engine was chosen for propulsion. We had most of the furniture stripped from the deck and the deck railings removed on the forward half of the boat so that the sensor platform could be stored and transported on the deck. A marine winch was installed on the deck to lift and deploy the sensor platform. Marine hardware was installed to serve as tie-downs for the instrument racks and the generator. Mounting fixtures were designed and built for the tow point fixture, the GPS antennas, the depth sounder, and the imaging sonar.

Figure 2. The tow point fixture is located at the rear of the boat. The master GPS antenna is located on the mast above this point. The digital angular encoder measures the angle of the tow cable relative to the boat heading. The weak link cable is located between the shackles at the end of the tow arm.

The sensor platform is towed by a 16- or 22-meter cable attached to a custom tow point fixture located at the center of the boat at the stern, Figure 2. The maximum operational design speed is 5 knots. Assuming the system is used to survey 4-meter wide lanes at 5 knots, the survey production rate is 3.7+ hectares/hour, or slightly less than 10 acres/hour. The attitude and depth of the sensor platform is controlled by an autopilot operating from a computer on the tow vessel, Figure 3. The inputs to the autopilot include a tactical-grade IMU mounted on the sensor platform (determining pitch, roll, and yaw of the platform), depth sensors and digital magnetic compasses on both the platform and on the tow vessel, and a dual antenna GPS system on the tow vessel. The autopilot, which controls the sensor platform, can be programmed to either maintain a fixed standoff distance from the bottom or to maintain a fixed depth below the water surface. This system provides a truly unique capability for underwater UXO search systems. The survey products include digitally geo-referenced magnetic anomaly maps of metallic objects buried in the bottom sediments. The full array of dipole-based target analysis capabilities developed for the MTADS ground survey systems has been adapted for this application.

Figure 3. All sensor data are recorded by the computers in these data racks mounted across from the drive console, near the port rail.

The number of sensor systems operating and the complexity of the data streams far exceed any of the previously-developed MTADS arrays. This required that we have multiple computer systems on board, multiple data racks to accommodate them, and the full-time attention of a technician to monitor the data flow, Figure 3. The survey plan and the real time survey course are displayed on the Pilot Guidance display shown immediately to the right of the steering wheel in Figure 4. The digital readout from the forward depth sounder is shown to the left of the steering wheel.

Figure 4. The tow vessel console is located on the starboard side. The pilot is responsible for maintaining the survey course and avoiding bottom obstacles.

The primary Data Acquisition (DAQ) computer operates a version of the Geometrics Maglog® software adapted for this application. Maglog has been the primary DAQ GUI for all MTADS platforms. The sensors from the marine platform, except the EM68, are recorded in this utility. Additionally, the GPS data and data from the depth sounder are recorded using this GUI.

A new GUI that we developed to allow us to control and monitor the sensor platform behavior, was developed in SERDP Project UX1322[5] and is extensively described in the SERDP UX1322 Final Report.[6] Three primary operational control algorithms were developed for the sensor platform GUI. The first allows us to operate the platform at an operator-specified depth below the surface. The second mode is designed to operate the sensor platform at a specified height above the bottom. The third mode is referred to as the Emergency Rise mode. This can either be called from the keyboard or automatically invoked by pressing the Emergency Rise Button on the electronics rack console panel. In this mode, the elevators are driven to their full up stops and held there until the platform ascends to 0.5 m below the surface. This mode is intended for use if we observe a bottom obstruction that is likely to cause an impact with the sensor platform.

Figure 5. The assembled sensor platform is shown.

The sensor platform is a 5 m wide fiberglass structure, which basically has an airplane wing cross-section. Figure 5 shows an image of the entire structure floating in the water beside the pontoon boat. Figure 6 shows another image with the hatch covers removed. In this image several of the sensor components are identified. The sensor platform accommodates 8 Cs vapor full field magnetometers on a 0.6 m spacing and an EM array consisting of a 1 X 4.5 m transmit coil and four 0.5 X 1 m receiver coils.

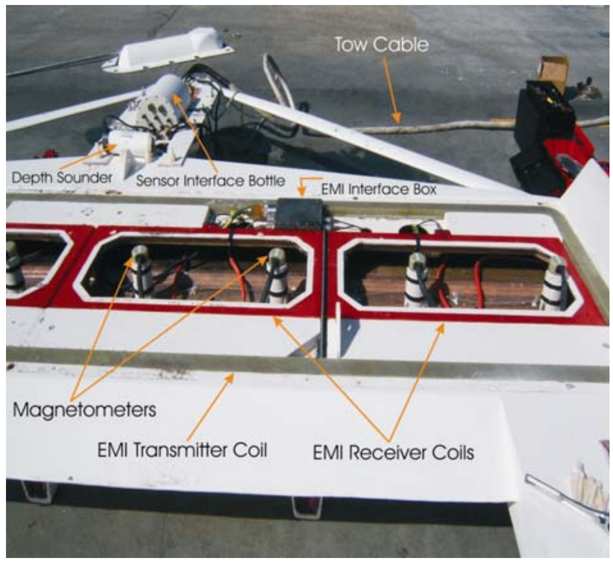

Figure 6. The marine sensor platform is shown with the hatch covers removed. Many of the system components are identified.

In case of a severe impact of the platform with some bottom structure, we have designed and installed a breakaway link in the tow cable, which will part at 1,100 lb tension. It is shown in Figure 2. The electrical connectors from the tow cable to the bulkhead connector at the rear of the boat are designed to part at 50 lb.; these cables can be wet re-mated.

2.2 Technology Development

The technology development was described in detail in the report of our initial demonstration, "The Marine Towed Array Technology Demonstration at the Former Naval Duck Target Facility."[2] We briefly review this information below.

The MTA system concept was developed in conjunction with Vehicle Control Technologies, Inc. (VCT) during SERDP Project UX-1322. We considered a wide range of platform design concepts, and evaluated their potential performances against the top-level requirements in both static and dynamic hydro-code modeling studies. Design concepts included bottom-following platforms (sleds or roller designs), towed submerged platforms (with solid booms or flexible cables), and hybrid platforms dynamically suspended from a towed pontoon platform.

The preliminary design resulting from the concept study was a wing-shaped fiberglass structure designed to be towed from a position well forward of the wing using a flexible tow cable, Figure 7. Pitch stability is provided by the (yellow) wing extensions. Weighted skids on the bottom of the platform provide stability to ward off inevitable bottom collisions. Roll and depth control are provided by the elevators (red) on the trailing edge of the wing extensions. The elevators are controlled by two actuators (gray).

The EM array is embedded in the structure; the magnetometers are in bottles (blue) that extend above the top of the wing surface and area covered by cowlings.

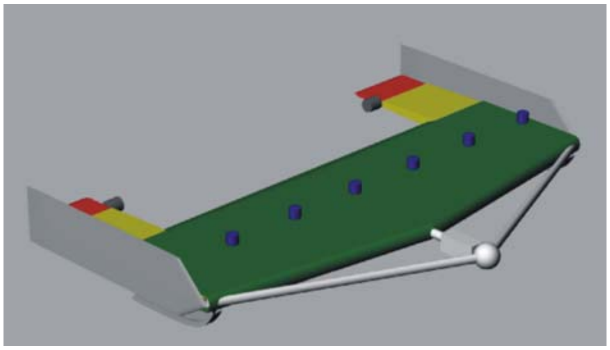

Figure 7. Perspective drawing of the 4-meter sensor platform concept.

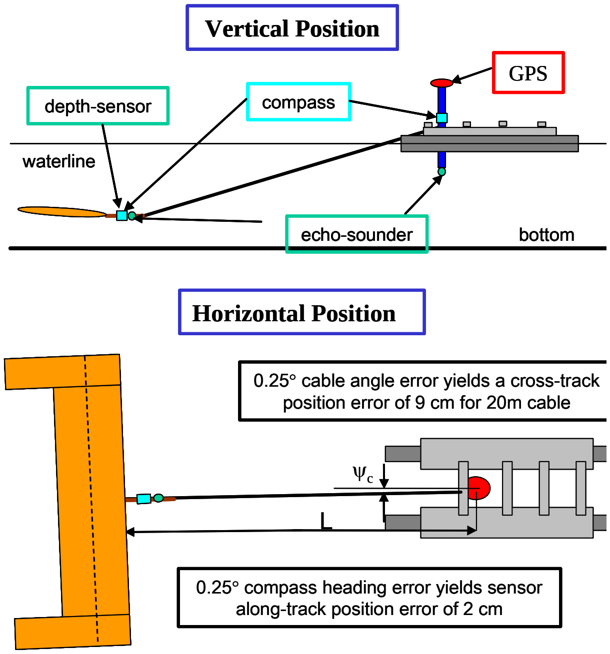

Figure 8. Sensor platform deployment concept resulting from SERDP Project UX-1322.

The concept design is shown in Figure 7. Here we have included general descriptions of the positioning sensors that are required to derive the coordinates of the individual sensors. The precise descriptions of the different positioning sensors are discussed in various SERDP project reports and in the Project Final Report.[6] The most sensitive measurement that must be made is the angle that the tow cable forms relative to the long dimension of the tow vessel, ψ_c, in Figure 8. The contributions to the complete positioning error budget were treated in a separate study, which was continually refined as the individual component choices were made and their performances evaluated. At the end of the SERDP Project, it was our prediction that we would be able to locate the sensor positions in the horizontal plane to <15 cm and in the vertical plane to <20 cm using this design.

The majority of the actual development work on the Marine Towed Array took place during the ESTCP Project MM2003-24.[7] Structural Composites, Inc. (SCI) joined the effort at the beginning of the ESTCP project. Working with the sensor platform concept designs and the results of the system hydrodynamic performance modeling, we developed a preliminary engineering design. This design was submitted to a Finite Element Analysis to validate the predicted system performance and the planned system design. Following the final system design review, SCI was contracted to produce the sensor platform.

We contracted with a separate firm, Ocean Marine Industries, to design the cable system for towing the sensor platform and to design the sensor interface container. The latter component is a waterproof cylinder that mounts on the sensor platform. Using underwater connectors, this unit serves as a bulkhead interface, mating all of the sensor leads on the sensor platform to the tow cable electrical input connectors. In addition, this container houses a magnetic compass, the Honeywell IMU, and some printed circuit amplifier boards.

The selection of the individual system components either flowed logically from the requirements developed in the modeling and engineering design studies, or resulted from testing of component performances using borrowed or rented components. In several instances, it was necessary to evaluate the interaction between the components, such as the actuators/cables and the magnetometers, when they were both operating.

Figure 9 shows a CAD drawing of the engineering design plan approved for Structural Composites to fabricate. To improve the sensitivity of the EMI system, the receiver coils were increased in size to a full 1-meter in width.

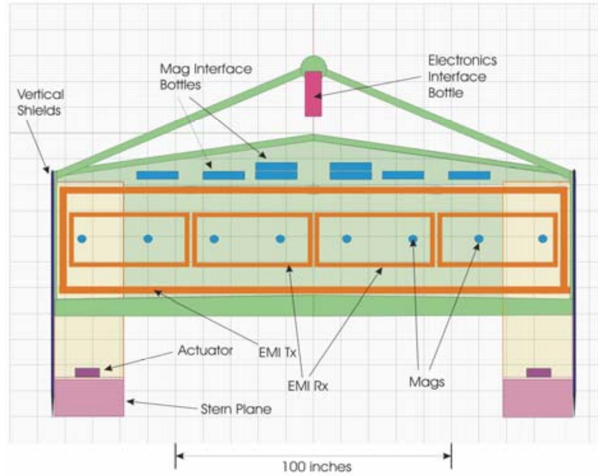

Figure 9. Schematic drawing of the marine sensor platform.

2.3 Advantages and Limitations of the Technology

The MTA system offers the first efficient and automated modern UXO survey capability that can provide fully geo-referenced survey products to support shallow water UXO clearance operations. As it is constructed, the Marine Towed Array is a very complex R&D system. It is likely too electronically complex, too heavy, and too expensive to be a competitive commercial instrument as it is currently configured. However, we have learned enough from its design, performance, and operation to design a field-worthy prototype that would likely weigh 60-70% less, and be self-contained and transportable on a single boat trailer.

Mechanically, we currently recognize two shortcomings of the system. It requires the use of an improved boat launch ramp to deploy and recover. In many marine areas this is a problem. Because of the way the Sound is used in Duck, it was a significant challenge during our first demonstration.[2] Because suitable facilities were not available, 2-3 hours of survey time was lost each day deploying and recovering the system. Very shallow water access and egress from marinas is an additional problem, as is very narrow access and turning requirements that are not compatible with the MTA with the sensor platform deployed.

A similar situation pertained in the Ostrich Bay demonstration. The closest marina with full capabilities for lifting and launching the MTA vessel with the sensor platform on the deck was in Seattle, 20 miles distant from the survey site. The MTA vessel was launched and driven at high speed to Silverdale where it was mated with the sensor platform. The Silverdale marina has an excellent boat launch ramp and docks; however it is 6 miles distant from the survey site.

We therefore set up mooring buoys in Ostrich Bay adjacent to Pier II where the completely assembled MTA was moored each night. The only way that repairs could be done that required removing the platform from the water was to ferry the system to Silverdale. Several repairs were made in the water using a diver from the mooring site in Ostrich Bay.

As a result of our shakedown studies, we decided that, using our current hoist system on the MTA tow vessel that it is unsafe to launch and recover the sensor platform from the deck of the boat while it is in the water. This situation could be remedied; however, it will require a significant system redesign, which we have not undertaken. For the foreseeable future, the sensor platform will be transported (and launched and recovered) using a second boat trailer.

Developing a new attachment on the tow cable permitted us to deploy a 22 meter cable, which allowed significantly extending our surveying capability into deeper waters. We were able to survey all areas in Ostrich Bay (except for a very small area southeast of Erland Point) by judiciously choosing the correct part of the tide cycle for working in deeper areas.

The cow catchers on the front of the platform serve to protect the leading edge of the platform from collision damage with boulders and broken off pilings. These fixtures are effectively sacrificial; a significant collision causes serious damage to them. Sometimes they can be repaired; however, either repair or replacement costs about $800 each and requires us to carry several spares.

3.0 PERFORMANCE OBJECTIVES

Unlike the first MTA demonstration in Duck, NC, our survey operation on Ostrich Bay was not directly coupled with an ordnance recovery operation. Our operations with the MTA were part of the larger site characterization and remediation project being conducted both on land and on Ostrich Bay. The design and installation of a seeded-target POS was sponsored by NAVFAC EFA-NW and implemented by NEODTD.[8] Target investigations and/or removals were undertaken during Phase 2 of the EFA Northwest Project several months after the MTA survey. Our operations on Ostrich Bay were therefore, non intrusive and did not require an Explosives Safety Submission, or a Diver-based UXO Health and Safety Work Plan. Our objectives were focused upon conducting an efficient and high-quality marine UXO survey of Ostrich Bay. We expected that geophysical marine ordnance surveys would be conducted by other commercial firms before any ordnance recovery operations were conducted. These additional surveys allowed the MTA system performance to be evaluated against other developing technologies. We also understood that the identity of the seed targets in the POS, their locations, and our detection performance on the POS would not be available to us until after the diver investigations were completed and the NAVFAC report of these activities was completed.

3.1 Statement of the Objectives

The primary challenges to the MTA performance at this site include:

- The highly variable bottom structure and water depths,
- The extremes of the tidal cycles,
- The geologically active (volcanic) nature of the underlying soils,
- The availability of only primitive launch and recovery facilities near the survey area,
- The unavailability of overnight docking or mooring sites within several miles of the survey area, and
- The long distances over which transportation and logistics issues must be worked.

The performance metrics that we established in the Demonstration Test Plan[9] for measuring the success of this demonstration include the following:

- System performance:
  - Establish on-site logistics to support efficient demonstration operations (Efficiency will be measured in lost time during the demonstration to establish required support),
  - Demonstrate efficient survey platform deployment and recovery operations (Efficiency will be measured in lost time at the beginning and ending of each day’s operations to deploy and secure the system),
  - Evaluate component performance including actuators, navigation and location sensors, depth sounders, and the imaging sonar

(Efficiency will be determined by the number and extent of breakdowns and work stoppages because of equipment failures and by having necessary spares to quickly recover),

- Survey performance of the magnetometer and EMI arrays:
  - Survey production rates will be reported as hourly and daily survey rates (acres/hour or acres/day) for each sensor array,
  - Maximize coverage area and minimize missed areas (Will be determined from course-over-ground and missed area plots),
  - Performance of the survey guidance system and the sensor platform autopilot; ability to lay out and prosecute a survey grid, and ability to follow underwater terrain and maintain the intended bottom separation (Will be determined by course-over-ground plots and plots of command depth [or altitude] *vs.* achieved platform depth),

- Data acquisition performance:
  - Efficient integrated performance of all systems supporting the autopilot, the pilot guidance display, and the magnetometer sensor data stream (Will be evaluated in the Demonstration Report), and
  - Performance of the EMI data acquisition system (Performance will be evaluated against the performance of the magnetometer array),

- Creation of data products:
  - Mapped data files and images,
  - Magnetometer and EMI target analyses,
  - Dig lists, and
  - Support for future target recovery.

As required by the Demonstration Plan Instructions, these objectives were reduced to tabular form in the Demonstration Test Plan. We separated the various component objectives into two lists; the first was referred to as quantitative objectives, the second as qualitative objectives. These lists are reproduced below in Tables 1 and 2**.**

Table 1 has a third column designed for inclusion of information relating to performance with respect to the individual objectives following the demonstration. This information has been filled in with sufficient detail that further narrative is not required. Additional information describing how some of the objectives were addressed and the system performance is provided in various sections of Chapter 7 of this report.

The performance against the qualitative objectives is more difficult to describe in a tabular format. We will describe system performance against the qualitative objectives relating to mobilization, demobilization, daily deployments and responses to equipment failures in this chapter. Other objectives addressing survey performance issues and creation of survey products are addressed in narrative fashion in various sections of Chapter 7.

Table 1. Marine towed array quantitative demonstration objectives

Primary Performance Criteria	Expected Performance	Actual Performance
Data preprocessing and creation of mapped data files	Accomplish Overnight for QA Purposes	Accomplished overnight in all cases
Target analysis and preparation of dig lists	Accomplish within 2 weeks of survey	POS analysis completed on site. Full Bay completed on time.
Magnetometry survey production rates	6 acres/hr while surveying in the open water areas	Overall survey rates in all areas was 3.2 acres per hour.
EM survey production rates	6 acres/hr while surveying in the open water areas	EM survey production rate on POS was 1.7 acres per hour.
Detection of POS targets	All targets labeled as large or very large in the POS Work Plan will be detected in mag and EM datasets	Target detection performance on the POS is described in the text of the report.
Target location accuracies	±35 cm, overall when surveying with short cable, ±60 cm when surveying with long cable	Accuracies were nearly equivalent with either cable. MTA location accuracies were better than the target installation or reacquisition accuracies.
Survey Coverage/Missed Areas	In areas intended for complete coverage, >95% coverage will be accomplished.	This was easily accomplished using fill-in surveys as required. This is described in other tables.
Depth station keeping	Command depth (or altitude) will be maintained within 0.15 m 95% of the time	This was accomplished. Difficulties arose when command altitude changes could not be accomplished quickly enough to avoid bottom collisions.
Line station keeping	During acceptable weather, 4 m survey lanes will reduce missed areas to <5%	This objective was accomplished.

All equipment failures, except for the Geonics EM array, were associated with mobilization and the initial equipment deployment. These involved loss of signal from one magnetometer, a nonfunctional actuator cable, and a broken GPS antenna. The magnetometer signal loss was the result of a software glitch in the Data Acquisition module, which was fixed after troubleshooting on-the-fly during the survey. The actuator cable was replaced from spare stock and the GPS antenna replacement was ordered by telephone for overnight delivery. All other breakdowns and equipment failures were associated with sensor platform collisions with bottom structure, broken off pilings, and large junk items abandoned around the piers. Broken weak links in the tow cable were replaced with a few minutes of lost time on each occurrence and broken or damaged "cow catchers" were replaced from spares using a diver while the platform remained in the water.

Table 2. Marine Towed Array qualitative demonstration objectives

Operational Component	Objective	Measurement Metric
Logistics and Support	Pre-establish necessary support logistics	Time lost during demonstration to correct deficiencies
	Efficient boat and survey platform deployment and recovery	Time lost at the beginning and end of each day to deploy and secure the system
	Provide system support and communication while at sea	Lost survey time to correct problems
	Provide onshore logistics to support data processing and data products	Timely processing of survey data for quality assurance
Equipment Component Performance	Platform attitude and position control to support precise navigation and location requirements	Number of breakdowns and work stoppages because of equipment failures or lack of spare components.
	Efficient performance and integration of ancillary components	Time lost or survey integrety compromised because of GPS, DIDSON sonar, boat-mounted depth sounders, or the pilot guidance system performance
Survey Operations	Maintain consistently high survey production rate.	Will be measured and reported as hourly and daily survey rates and also fraction of the day actually taking survey data
	Maximize coverage area and minimize missed areas	Will be measured using course-over-ground plots
	Achieve detection goals for individual targets	Mag and EM sensors will be evaluated against the emplaced POS targets and the two sensors performances will be measured against each other
	Pilot guidance system provides capability to achieve survey goals	Performance will be evaluated with course-over-ground plots in varying sea states and weather conditions
Data Acquisition Performance	Efficient integration of all components supporting the pilot guidance display, the platform autopilot, and the data acquisition system	Will be evaluated by the ability to lay out and survey to a prepared grid, by the extent and severity of track misregisterations, and by the ability to fly the platform on a straight and level course
	Conduct an efficient EMI survey	EMI survey performance and detection capability will be measured against the magnetometer survey performance
	Successful performance of the imaging sonar	Performance will be evaluated imaging areas around piers and moorings
Data Products	Overnight data preprocessing	Preprocess and correct survey data
	Timely target analysis	Target analyses completed for preparation of reports and to support intrusive work
	Timely preparation of dig products	Prioritized dig lists prepared as described in Work Plan

3.2 Performance of the EMI Array

Following the system demonstration in Duck, NC[2] the EM array system was extensively redesigned by Geonics. This included modifications to the electronics in the interface box which resides on the sensor platform adjacent to the coils, and software modifications to the data acquisition system. These were intended to improve the Signal/Noise characteristics of the system and to make it more resistant to water damage. These changes were made to our equipment by Geonics factory representatives in our Cary, NC offices and they accompanied us on shakedown tests of their equipment on an MTA deployment on a lake near our facility. The system operation was improved, but still did not fully meet initial purchase specifications.

The EM array was activated on the second day of surveying on Ostrich Bay to survey the POS. The overall system noise was again in somewhat degraded over its performance in the lake tests and one of the receiver coil data channels had an intermittent spiking noise problem. We completed the POS EM survey, but when we moved to survey the Calibration Line (in deeper water) the EM system completely failed. Troubleshooting did not reveal any problems that could be addressed without removing the sensor platform from the water and disassembling the system to remove the EM interface module. We did not delay the survey operation, because it would have required at least a full day to transport the system to Silverdale, conduct the required operations and to redeploy to Ostrich Bay. When the survey was completed, we removed the EM sensor interface box – it was filled with seawater.

3.3 The Mobilization and Deployment Objectives

To conduct an MTA survey at a distant site, the equipment is transported using a 45 ft flatbed trailer. If the trailer is standard height (rather than a "lowboy" design), the wheels have to be removed from the MTA boat trailer to remain within the 13.5 ft overall height limit. The sensor platform is loaded onto the deck of the MTA vessel, Figure 10. The tow cables are shipped in a wooden palletized crate. The other equipment is packed into 4 X 4 ft plastic shipping containers. A few items such as the tow point assembly must be secured directly to the deck of the trailer.

Figure 10. The entire MTA system is shipped on the deck of a 45 ft trailer.

Figure 11. A small fork lift is used to unload the crated equipment from the shipping trailer into a rented box truck.

Because there were no accessible loading docks near the work site, equipment was unloaded with a fork lift and a boat lift, at the Shilshole Marina in Seattle. See Figures 11-13. The Shilshole Marina is about 20 miles from Silverdale by water (through Puget Sound) and about 50 miles from Silverdale by highway. At Silverdale there is an excellent public boat launch ramp and dock (about 6 miles by water from the Ostrich Bay work site); but there are no facilities there to unload the boat and boat trailer. Consequently, the initial staging took place in Seattle. The MTA vessel was launched at the Shilshole Marina and driven through Puget Sound for about 20 miles through the Port Washington Narrows to the Silverdale Public Marina. **Figure 14**[10] provides a perspective for Ostrich Bay and the nearby features. All the MTA equipment was loaded into a rented box truck and the sensor platform was loaded onto the MTA vessel boat trailer at Shilshole Marina. The box truck and the rental SUV (towing the boat trailer) were transported to Silverdale where the sensor platform was assembled and mated with the MTA tow vessel in preparation for surveying. During the entire period of the survey

Figure 12. A larger hoist is used to unload the sensor platform and later load it back onto the MTA vessel boat trailer. It cannot be lifted from below with a fork lift.

Figure 13. A large marine hoist is used to unload the MTA vessel and the trailer together. It is difficult to lift the vessel alone without damaging the pontoons.

Figure 14. This is a 1998 aerial photo of Ostrich Bay and surrounding areas. This photo is not Ortho-corrected; the features appear compressed in the vertical dimension.

operation the MTA tow vessel and the sensor platform were moored in the evenings adjacent to the north side of Pier II in Ostrich bay. Figure 15 shows the mooring arrangement.

The Chase Boat, Figure 16, was used to support the MTA vessel during surveys. It was manned by a dive-certified UXO technician who carried out several in-water repairs during the demonstration. The Chase Boat was also used for commuting to and from the MTA vessel morning and evening. NAVFAC has a secure compound area in Jackson Park very near Pier II. Tetra Tech (a NAVFAC support contractor) has two office trailers in this compound. We had access to and use of one of these trailers during this demonstration. The box truck with our equipment spares was also parked in this secure facility. While there is no accessible pier or dock on Ostrich Bay (Pier II is 6-18 ft above the water surface), the Chase Boat could be beached on Erland Point if a part had to be picked up from the Tetra Tech Compound. Alternatively the part could be lowered from the top of Pier II by rope down to the Chase Boat.

Figure 15. The MTA vessel and sensor platform are shown moored on the south side of Pier II.

Figure 16. The Chase Boat was launched from the Silverdale Marina.

The GPS base station point was located on the deck of Pier II, Figure 17. Batteries had to be changed out each day at the base station. There is a locked gate between Pier II and the mainland, which provided security for the GPS equipment. It was not removed until the end of the demonstration. One of our crew members operated out of the Tetra Tech office trailer each day. He carried out data processing here, changed out the GPS batteries in the morning, and provided a communication link to other crew members on the boat. Additionally, he had access to a vehicle and could run any errands relating to immediate needs to support the crew on the boat. The MTA survey crew and the chase boat crew members commuted morning and night from the marina where the chase boat was docked.

Figure 17. The GPS base station is shown set up on the Primary Control Point, which was established during earlier operations.

This approach allowed us to most efficiently address the mobilization and deployment objectives enumerated in Tables 1 and 2. The objectives specifically related to the survey operation are addressed in more detail in the subsections of Chapter 7 of this document.

4.0 SITE DESCRIPTION

The second demonstration of the Marine Towed Array (MTA) was on Ostrich Bay adjacent to the current Jackson Park Housing Complex and the Naval Hospital Bremerton. This area has an ordnance history stretching back more than 100 years. The "Archive Search Report," published in 2002 succinctly describes the site history.[1] The brief description below was adapted from this document.

4.1 Site History

The Naval Ammunition Depot Puget Sound was established in 1904 on 255 acres on the shore of Ostrich Bay two miles northwest of Bremerton, WA. Initial operations at the depot involved storing smokeless and black powder and producing relatively small caliber gun ammunition (3-in and 4-in). In 1916 the facility was commissioned as Naval Magazine Puget Sound; the depot then comprised 25 buildings, an ammunition-loading pier, and a narrow-gauge railroad to move materials around the facility. Over time the depot expanded to include more types of ammunition on the production line; high energy materials included Explosive D, TNT, and Composition A. When World War II began in 1939, the depot included 185 buildings with a workforce of >200 people. At that time the production line produced ammunition ranging from 3-in to 16-in projectiles. The depot also stored large quantities of munitions that were not produced on site, including small arms ammunition and bombs. At the end of World War II, depot personnel had peaked at nearly 2,000. After the war the depot declined, and the newly commissioned NAD Bangor became the main facility in the group.

Four piers were constructed and used during the history of the NAD Puget Sound to transfer explosives components and live ordnance back and forth between seagoing vessels and the facility and to support vessels awaiting dock space. Not being a deep water port, these transfers took place using barges (or lighters), which shuttled between the port and the ships docked in nearby deep water ports. Pier 1 was constructed prior to 1913 and was operational until 1959. It was demolished in the 1970s. Pier II was constructed in 1940 and was operational until 1959. A railroad transfer pier was also constructed in 1940. It was converted into a recreational fishing pier in 1982. The railroad pier has also subsequently been demolished. Piers I and II were used to unload ammunition from barges using deck cranes. Ammunition from incoming war ships was unloaded onto barges and the barges, or lighters, were piloted into the shallow waters of Ostrich Bay. During World War II, up to 200,000 pounds of explosives were unloaded per month. The railroad pier was used to load and unload entire railroad cars from barges. Little or no ordnance was likely lost into the water in these operations. Figure 18 shows a historical photograph of the NAD complex and the features discussed above. The photograph[10] is undated, but was likely taken in the late 1940s.

NAD Puget Sound was closed in 1959. In the years following closure, the size of the depot area was reduced by transfer of property to GSA and sale of property to Washington State, Kitsap County, the City of Bremerton, and to private land owners. In 1975 the remaining property was transferred to the Puget Sound Naval Shipyard, renamed as the Jackson Park Housing Complex, and developed as high-density residential housing for military personnel. In

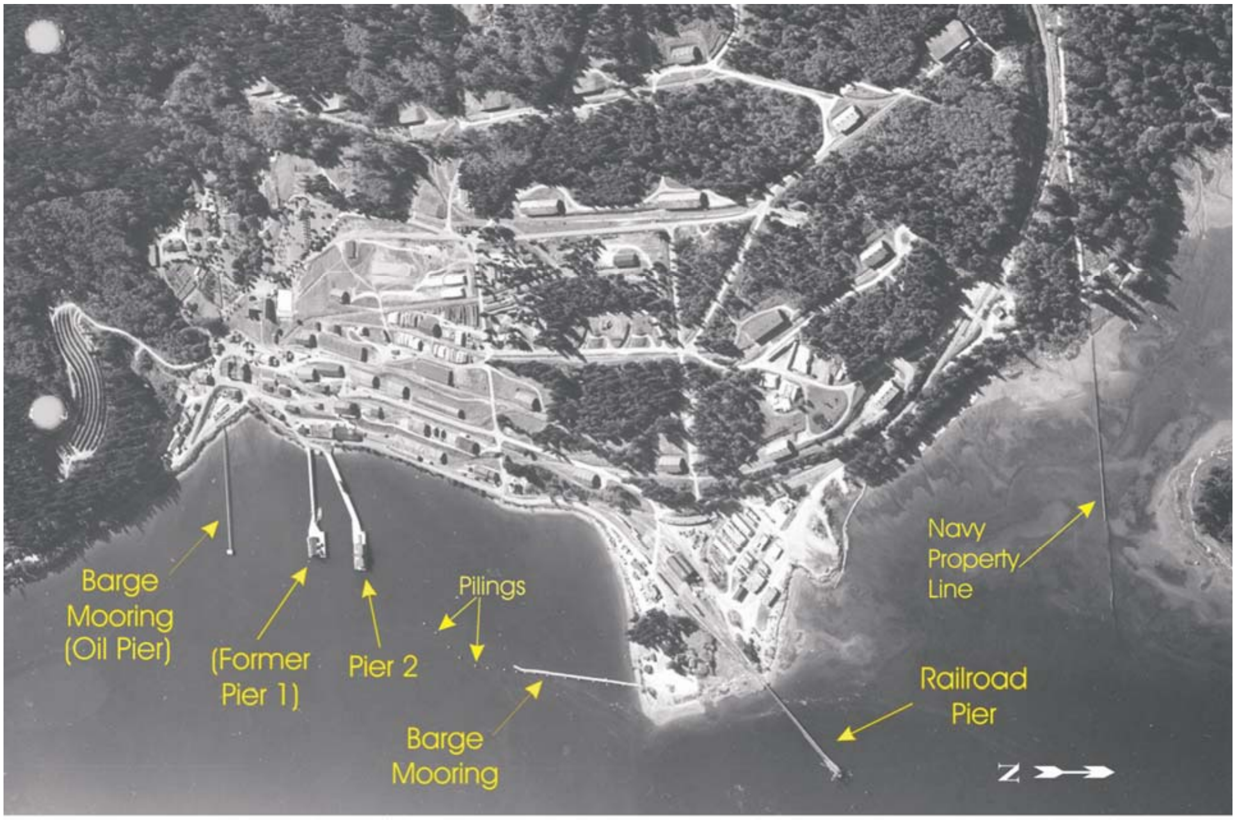

Figure 18. A part of Ostrich Bay adjacent to the Naval Ammunition Depot Puget Sound is shown during the period of its peak operation. All the labeled features except Pier 2 have been removed before our survey. Some of the pilings were broken off (above the bottom surface) rather than being removed.

1977, 49 acres was transferred to the Naval Regional Medical Center on which the Naval Hospital Bremerton was constructed.

4.2 Site Selection for the MTA Demonstration

Beginning in 1980, significant ordnance cleanup activities were undertaken. These began on the Bay to allow removal of many of the structures and to make the remaining structures safer for potential future uses. The focus of activities then moved onto the land where they remained for several years. Most recently they have begun to include activities on the Bay again.

4.2.1 Ordnance Recoveries and Cleanups: In the fall of 1980 and the spring of 1981 Navy EOD divers conducted an extensive ordnance recovery operation in the area of Pier II and the dolphin piles to recover ordnance. The search was made using jackstays or rods to probe the sediment every few inches. A total of 18,708 discarded military munitions (DMM) items were recovered. These are summarized in Table 3. Of this total, only 58 items were declared to be inert. A total of 17,149 pounds of DMM with an explosive weight of 3,877 pounds was recovered.

4.2.2 Modern Environmental Activities: The demonstration of the MTA is a small part of a larger set of studies and clearances that have been ongoing at the Jackson Park Housing

Complex and the adjacent Ostrich Bay areas for nearly a decade. These operations have been conducted under the Comprehensive Environmental Response, Compensation, and liability Act (CERCLA) using two different types of actions: Record of Decision (ROD) actions for Operable Unit 1 (OU1) and a Time-Critical Removal Action (TCRAs) for OU 3. In addition, limited investigations at the ammunition piers and in Ostrich Bay (within the Navy property boundaries) were conducted as part of the MEC clearance activities. The offshore areas are within OU 3M. The Final Archive Search Report[1] and the Final Abandoned Ordnance Report Volume 2 September 1999 to December 2001[11] document the historical record that we have drawn on in preparation for the MTA demonstration.

During the first half of 2005 discussions took place involving NAVFAC EFA Northwest, AETC, and the ESTCP Program Office exploring the possibility of the AETC MTA platform being used with the support of ESTCP to conduct a UXO survey operation on Ostrich Bay. AETC's active involvement began in late 2005 with preliminary studies that did not involve the MTA.[12]

Table 3. DMM recovered during the 1980-1981 clearance in Ostrich Bay[12]

Ordnance Description	Quantity Recovered
22 Caliber Cartridge	5
45 Caliber Cartridge	6,105
45/70 Caliber Cartridge	15
30.06 Caliber Cartridge	973
50 Caliber Cartridge	1,372
1.1-in, 75 Caliber Cartridge	29
20-mm HE	8,022
Primers	245
Fuzes	142
Flares	102
Grenades	2
3-in Propellant Charge	2
5-in Propellant Charge	9
5-in Training Round	7
5-in/38 H.E.	41
MK 23 Practice Bomb	7
Hedge Hog Warhead	1
105-mm Projectile (inert)	30
3-in/50 All Up Round	26
3-in/23 Projectile	1
40-mm All Up Round	1,554
100-lb GP Bomb (inert)	1
500-lb GP Bomb (inert)	11
1000-lb GP Bomb (inert)	4
16-in Projectile (inert)	2

4.3 Site Geology

Ostrich Bay is near the southern end of the series of bays, inlets, and marine estuaries that form the Puget Sound system. It is many miles from the Ocean inlet, but because of the very high tides in the region (averaging 10-12 ft) the bays are filled and flushed twice each day and are fully marine. Species of concern in Ostrich Bay include Killer Whales and several species of fur-bearing marine life. The whole area is mountainous, and of volcanic origin. The bottoms of the bays may be very deep in homogeneous silt, or may have exposed outcroppings of bedrock. Magnetic geologic interferences are very localized and may be quite intense (see below).

4.4 Munitions Contamination

Our working premise was that the ordnance that we expected to encounter could be described by the inventory of recovered ordnance from the 1981 clearance that was conducted around the perimeter of Pier II. This was conducted by divers who probed the bottom with jack stays in search of solid objects. The range of ordnance recovered varied widely in size and type, but we must remember that NAD Puget Sound was used for ordnance manufacture and assembly as well as serving as a depot storage area for the Navy and Naval Air services.

5.0 DEMONSTRATION DESIGN

As described in Section 4.2, the MTA marine survey on Ostrich Bay is one component of a much larger ongoing set of environment operations taking place both on land and in Ostrich Bay offshore from the former NAD Puget Sound. NAVFAC EFA Northwest is the agent responsible for coordinating and operating all of these activities. They are being carried out in cooperation with the current tenants, The Jackson Park Housing Complex, The Naval Hospital Bremerton, the Suquamish Tribe, the residents of the communities surrounding the Bay, and the State and National EPA. Many of the documents describing these related activities are cited above. Electronic copies of several historical NAD Puget Sound documents that are relevant to this demonstration are included in **Appendix B** to this report.

5.1 Conceptual Experimental Design

The concept involved in the MTA UXO survey demonstration is quite simple and is basically described in the enumeration of the demonstration objectives in Section 3.1. In short, the intent of our demonstration was (1) To use the MTA to survey the POS and the Calibration Line and present the results to NAVFAC showing that the MTA was qualified to conduct the remainder of the study, (2) To use the MTA to conduct an efficient and comprehensive survey of the potentially MEC-contaminated areas of Ostrich Bay, and (3) Process and analyze the survey data and reduce it to a prioritized target list that NAVFAC could use to evaluate our success and subsequently use to remove potentially dangerous DMM from Ostrich Bay.

5.2 Site Preparation

In the fall of 1980 and the spring of 1981 Navy EOD divers conducted an extensive ordnance recovery operation in the areas of Pier II and the dolphin piles to recover ordnance. These activities were described in Section 4.2.1 of this report.

As part of the OU3M study of the 79 acres of marine Navy property (to the 4 fathom line adjacent to the JPHC and the Naval Hospital), a bathymetric survey of Ostrich Bay was conducted in January 2004.[13] Data were collected using a 455 kHz SeaBat Model 8125 and processed using HySweep multibeam software. A combination of automated and manual data editing was used. The high resolution data were degraded to a 3 X 3 ft resolution and used to plot a bathymetry map. A false color version of the map is shown in Figure 19. See also Appendix B of this document.

The top layer shows the outline of the current area occupied by Pier II. The depth contours are not visible at this scale. The deepest part of the Bay (about 40 ft at low tide) lies immediately southeast of Erland Point. The dredge areas surrounding Pier II are evident, as are the bottom disturbances in the area of the Former Pier I and Railroad Piers. Bottom disturbances are also evident north and east of Pier II where the pilings associated with the dolphin moorings were removed.

Figure 20 shows a grayscale presentation of a part of the same data, which focuses on the areas surrounding Pier II and the former Pier I. The contour lines, which are plotted on 3 ft intervals show the sheer walls of the dredge cuts that remain surrounding Pier II. On the north side of the Pier, the dredge cut walls are almost 15 ft high. The disturbances northeast of Pier II show the remains of the activities where the dolphin pilings were removed. At the right side of the image, the bottom of the Bay appears to be covered with rocks. Careful examination reveals that these features are less than 1.5 ft high.

In November 2004 a Sidescan sonar survey of Ostrich Bay was conducted as part of the same OU 3M study.[14] EdgeTech Model DF100 and Klein 5500 units were deployed from a tow fish. Data were processed using Hypack MAX software to rationalize adjacent survey lines and to attempt to position register the data with GPS positioning on the boat. Because GPS quality was typically DGPS or worse, the sum of the positional errors yielded an estimated positional accuracy of ±4-11 meters. The report produces data clip images of various bottom features.

The stated purpose of the data is to provide guidance to future surveys to avoid structural features.

Figure 19. False color bathymetric image of Ostrich Bay overlaid on a recent aerial photograph of the area.

During the fall and winter of 2005 operations were undertaken by NAVFAC EFA Northwest to define the OU 3M activities planned for implementation of the RI/FS associated with Ostrich Bay. These operations were divided into two phases. The Reconnaissance Survey work done by AETC formed a part of the defined activities of Phase 1 of the RI/FS. These activities are described in the Reconnaissance Survey Report,[15] which is included electronically in Appendix D of this document. The results are summarized in Table 4. Following the AETC reconnaissance survey, the primary activities undertaken during the winter of 2005-2006 and the spring of 2006 included planning for the design and location of the POS. EFA-NW coordinated the identification and availability of inert ordnance items conforming to the list in Table 3.

The Naval Explosive Ordnance Disposal Technology Division, 2008 Stump Neck Rd., Indian Head, MD was chosen by EFA Northwest to manage the installation of the POS to support future UXO survey activities. The Test Plan for the operation was developed and went through several draft stages before acceptance. The document is titled "Work Plan for Marine Geophysical Prove-out Installation at OU 3M Jackson Park Housing Complex, Ostrich Bay."[16] Using divers and surface support vessels, the installation activities were completed in April of 2006. The specific locations of individual targets and the numbers of targets in each ordnance category was held confidential by EFA-NW until all potential users of the site completed their POS surveys. The Work Plan for the POS installation is included as an Appendix E of this document.

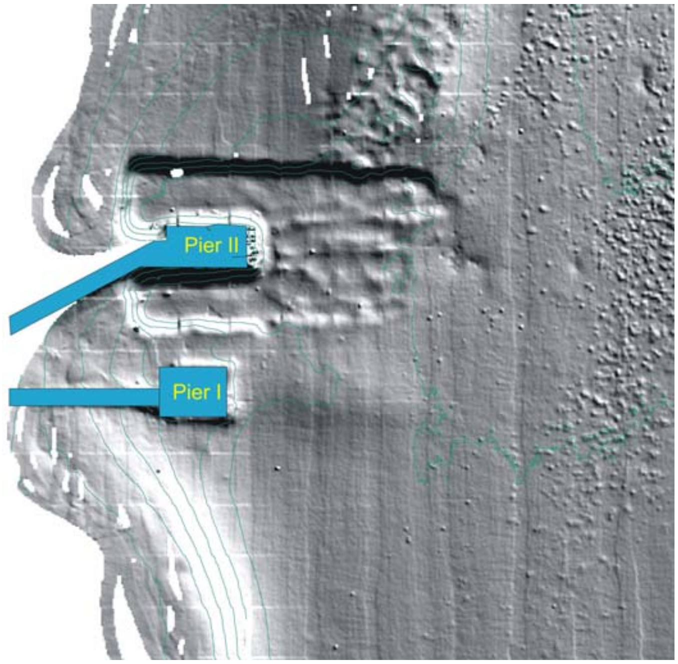

Figure 20. A bathymetric image of the bottom structure around Pier I and Pier II is shown.

The installation of the POS and the performance of the two demonstrators at the site are described in the report, "Ostrich Bay Underwater Geophysical Prove Out, After Action Report, Operable Unit 3 – Marine."[17] This document in electronic format is also included in Appendix E of this report.

5.3 Calibration Activities

Most of the components of the MTA are self calibrating, e.g. their output is based upon digital counting of frequencies, internal QC analyses automatically carried out by the GPS components on boot up, etc. All mechanical operational components of the MTA are tested on power up. Internal diagnostic routines are run and presented as displays for each of the magnetometers during their warm up. Magnetometer output readings are available both digitally and as waterfall displays at all times. If there are noise problems or offset problems associated with the individual units, they area visible in the displays. There are continual updates from all the sensors on the sensor platform displayed digitally, as are the readouts of the platform altitude, pitch, roll, and yaw. The Pilot Guidance computer displays in real time the system position relative to the planned survey grid, the direction and distance off course, the vessel heading, the water depth (and its rate of change), the distance and predicted time to the end of the current survey line, etc. At any time during the course of survey operation we were never more than a few minutes away from the 19 installed targets that were placed in the Calibration Line in the center of the Bay. If any aspect of the operation was in doubt we could just rerun a pass over the calibration targets.

Table 4. Phase 1 and Phase 2 Activities Under the RI/FS

PHASE 1	
Activity	**Due**
1. Mapping the degree of metallic saturation in the area of Pier II.	Completed 10/05
2. Pre-survey of several areas which are representative of Ostrich Bay water depths and bathymetry to determine if an area has minimum magnetic clutter for effective placement of the test bed.	Completed 10/05
3. General design of a test bed that is representative of types of DMM that may be present within Ostrich Bay's shallow and deep waters.	Completed 1/06
4. Finalization of the test bed design including loction and depth in the sediments of the particular items to be placed.	Approved 2/06
5. Placement of the inert DMM and surrogates in the test bed by divers from NAVEOTECHDIV	Completed 3/06
6. Solicitation of interest for screening underwater technologies	March 2006
7. Screening of underwater detection technologies for potential demonstration in the test bed.	April 2006
8. Geophysical survey of the test bed by the MTA as an ESTCP-sponsored demonstration.	May 2006
9. Wide area survey of Ostrich bay using the MTA, including diving on selected targets.	May 2006
10. Evaluation of other marine detection systems at the test bed, depending on the technology screening results.	June-Sept./2006
11. Submit secondary deliverable -- Draft Geophysical Prove-out of Marine MEC Assessment Technologies.	October 2006
12. Evaluation of geophysical technologies and investigative approach for subtidal areas of Ostrich Bay based on the results of the test bed demontration, generation of a draft Phase 2 RI/FS WP.	February 2007
Phase 2	
1. Grab samples in Ostrich Bay for propellant grains and small arms.	April 2007
2. Performance of a transect-based reconnaissance on the southern and eastern shore of Ostrich Bay to determine if DMM may be present in the intertidal area.	April 2007
3. Potential marine geophysics investigation and diving, scope to be defined following test bed demonstration and outlined in a Phase 2 RI/FS Work Plan.	June 2007
4. Evaluation of remedial alternatives for Ostrich Bay.	August 2007
5. Submittal of Draft RI/FS Report.	December 2007
6. Final RI/FS Report	May 2008

5.4 Data Collection

5.4.1 Survey Logs and Data Files

In the Final Version of the Demonstration Test Plan,[9] and in our agreement with the NAVFAC Site Manager Mr. Mark Murphy, it was specified that we would first survey the Prove Our Site (POS) and the Calibration Lane using both the magnetometer and EM arrays, process and analyze the data, and present NAVFAC with our analyzed results before beginning surveys in the remainder of the Bay. The POS was located in a 50 X 200 m area north of Madrona Point. The Calibration Lane was located along a N-S line about 110 m east of the western edge of the POS. Each site contained inert ordnance items representative of those expected to be found in the Bay. The POS and Calibration Lane were installed by NAVFAC Northwest, working with EAC, the Bremerton EOD Detachment, and NEODTD who managed the installation activities.[17] The Ground Truth in the POS was unknown to us until the NAVFAC Vendor Performance Document was released in final form.

The daily log of our demonstration operations is shown in Table 5. The log of the survey data files is shown in Table 6.

A total of about 214 acres of survey data were taken. These were collected during about 65 survey hours, based upon the length of the edited survey data files. The EM array operated only for a short period of time while surveying the POS. The data quality was inferior, characterized by a high S/N level. It was of minimal value in the POS analysis. No useful EM data were taken on the main survey site. When the sensor platform was pulled from the water, the EM interface box in the sensor platform was determined to be filled with sea water.

5.4.2 The POS and the Calibration Line

The Calibration Lane: The Calibration Lane was surveyed in the late afternoon during the first day of survey work. The tide cycle was such that the water depths over the targets varied between 6.9 and 7.6 m. The Calibration Lane was surveyed only with the magnetometer array. The EM array did not operate satisfactorily after the initial survey on the POS. The magnetic anomaly image of the Calibration Line survey is shown at two different sensitivity scales in Figure 21. Targets 8 and 12 (and perhaps 9) were not detectable in this survey. Targets 8 and 12 were a Mk2 grenade and an unidentified fuze, each buried 8 in deep in the sediment. Target 9 was a cluster of 20 mm projectiles.

Table 7 shows the spreadsheet, which contains the analysis of the target signatures and the ground truth information that was provided to us before the survey. Targets 10 and 11 appear to have moved approximately 1.5 meters from their original reported positions. Overall, the difference between our analyzed and the NAVFAC-reported positions of the targets averaged 0.61 meters.

Table 5. Demonstration Operations Log.

Date	Operation	Result
12 June 2006	Mobilization	Loadout MTA onto Tractor Trailer in Cary, NC
		Truck departed Cary at 1430.
14 June Wednesday	Mobilization	Jim, Chet, Chris, Nagi to SEA. Osborne from EOTI to SEA.
		Rented box truck and pickup. Trucker delayed until 6/17.
15 June Thursday	Mobilization	Chase boat delivered to Ttech Compound. EOTI rented dive equipment.
16 June Friday	0900 Met with Navfac and Ttech	Reviewed bathymetry maps, identified broken off pilings.
	Traveled to Seattle (Shilshole Marina)	Made arrangements for fork lift to unload trailer and boat hoists to launch boats.
17 June Saturday	Met tractor trailer	Unloaded equipment. Repaired Johnson engine. Launched MTA vessel, ferried it to Silverdale boat slip.
		Box truck with equipment and sensor platform towed to Ttech compound.
18 June Sunday	Launch system, Check out	Assembled platform and boat. Launched system. Discovered electronics glitches.
		Replaced actuator cable, trouble shot mag and GPS clock antenna. Ordered replacements.
	Begin survey at 1500	Mag survey of Cal site and part of POS
19 June Monday	MTA Survey	Complete mag and EM survey of POS
		Mag survey 23 lines on west side, north of Pier II.
20 June Tuesday	MTA Survey	EM survey of Cal Line, EM malfunction
		Mag survey N&S of pier, broke weak link, broke cowcatcher, Repaired GPS UTC time sync.
		Broke multiple weak links.
21 June Wednesday	MTA Survey, Mag Analysis	Mag survey east side N&S of pier. Completed DAS analysis of Cal Line and POS. EM analysis software not working.
22 June Thursday	MTA Survey	Long line mag survey middle of bay. EM software fixed.
		Finished mag/EM analysis of Cal Line and POS. Delivered results to Prog. Office, Navfac, EPA.
		EM hardware fix unsuccessful.
23 June Friday	MTA Survey	Long line mag survey middle of bay & West side fill in at high tide.
		Repair complete, all 8 mags operting.
24 June Saturday	MTA Survey	Mag survey of middle of bay, fill in missed areas, began Erland Point grid.
		DAS analysis of mag data on main site, prepare briefing.
25 June Sunday	Rest Day	Continued DAS analysis and preparation for NAVFAC/EPA briefing.
26 June Monday	MTA Survey	Fill in long lines on east edge of survey, fill in Erland point grid.
		Conducted briefing for NAVFAC and EPA, 1000 hours.
27 June Tuesday	MTA Survey	Last fill in mag survey lines in AM. All equipment to Silverdale Marina at Noon.
		Dismantle equipment, pack into trucks and onto trailers.
28 June Wednesday	Packout	MTA vessel ferried Silverdale to Seattle/Shilshole Marina.
		Box truck and pickup with platform trailer to Shilshole.
29 June Thursday	Demobilization	Haul MTA vessel. Load all equipment onto tractor trailer.
		Return rental vehicles.
30 June Friday	Demobilization	SEA to RDU

Table 6. Survey Data File Log

File Name	Tow Cable Length	Sensor Array	Survey Location	Survey Time (min)	Acres	Comments
18-4	22 m	Mag	Calibration Line	38	1.3	GPS UTC Sync not Working. Only 7 Mags Working.
18-5	22 m	Mag	Calibration Line	19	0.7	3 Lines Repeated in Opposite Direction.
18-6	22 m	Mag	POS	98	1.8	
19-1	22 m	Mag	POS	85	2.1	
19-2	22 m	Mag	POS	55	1.1	
19-3	22 m	EM	POS	149	4.2	75 Hz
19-4	22 m	Mag	PIER II North	87	4.1	
19-5	22 m	Mag	PIER II North	54	2.8	
19-6	22 m	Mag	PIER II South	55	2.8	
20-1	16 m	Mag	PIER II North	110	2.0	Broke Weak Link
20-2	16 m	EM	Calibration Line	28	1.1	75Hz not Working Properly.
20-3	16 m	Mag	PIER II South	7	0.5	Broke Weak Link; Broke Cow Catcher
20-4	22 m	Mag	PIER II South	12	0.5	Repeat of 20-3
20-5	22 m	Mag	PIER II South	189	9.6	GPS UTC Sync Repaired
21-1	16 m	Mag	PIER II N&S	52	1.1	Broke Weak Link
21-2	22 m	Mag	Main Bay	118	9.4	
21-3	22 m	Mag	Main Bay	54	4.1	Broke Weak Link
21-4	22 m	Mag	Main Bay	149	9.0	
22-1	22 m	Mag	Main Bay	181	11.9	
22-2	22 m	Mag	Main Bay	123	9.4	
22-3	22 m	Mag	Main Bay	45	3.1	
22-4	22 m	Mag	Main Bay	76	4.5	
22-5	16 m	Mag	PIER II N&S	205	11.1	
23-1	22 m	Mag	Main Bay	110	7.8	
23-2	22 m	Mag	Main Bay	212	17.3	
23-3	22 m	Mag	Main Bay	16	1.1	Repair Complete. All 8 Mags Working
23-5	22 m	Mag	Main Bay	13	0.6	
23-6	22 m	Mag	Main Bay	106	4.7	
23-7	16 m	Mag	PIER II N&S	72	3.1	
23-8	22 m	Mag	PIER II N&S	68	2.1	
23-11	22 m	Mag	PIER II N&S	84	2.5	
24-1	16 m	Mag	PIER II N&S	112	3.1	Fill In Missed Areas
24-2	16 m	Mag	PIER II N&S	45	1.6	
24-3	16 m	Mag	PIER II North	22	0.9	
24-4	16 m	Mag	Main Bay	59	3.7	Fill In Missed Areas
24-6	22 m	Mag	Erland Point	101	5.9	Begin Erland Point Grid
24-7	22 m	Mag	Erland Point	77	3.5	
24-8	16 m	Mag	Erland Point	101	4.4	Vessel Altimeter Changed.
24-9	16 m	Mag	Erland Point	99	4.9	
26-1	22 m	Mag	Main Bay	153	9.4	Fill In Main Bay Lines
26-3	22 m	Mag	Main Bay	141	12.6	Extend Survey to the East
26-4	22 m	Mag	Main Bay	104	9.4	
26-5	22 m	Mag	Main Bay	33	3.1	
26-6	22 m	Mag	Main Bay	52	4.7	
26-8	16 m	Mag	PIER II South	115	4.8	Fill In Missed Areas
27-1	16 m	Mag	Erland Point	101	4.4	Fill In Missed Areas
TOTALS				**3985**	**213.8**	

Targets 5 and 11 have signatures that are dominated by remnant moments, which are larger than the natural induced signatures of the targets.

Targets 17 and 18 were placed so close together that their signatures substantially overlapped at all presentation scales. They were mechanically separated for analysis purposes.

The POS Survey: The POS was surveyed on 18 and 19 June using the magnetometer array and on 19 June with the EM array. Figure 22 shows a magnetic anomaly dipole image of the entire POS from the magnetometry survey. The boundary of the POS is shown as the 50 X 200 meter white rectangle in Figure 22. The POS is located immediately north of Madrona Point (see Figure 14). This area is subjected to strong tidal currents (of up to 5 kts) four times a day as the 9-12 ft tide swings fill and empty Oyster Bay (to the south) through this small cut. The currents apparently scour the silt layer from the bottom of this area of the Bay, exposing the underlying geologically active bedrock. Compare the intensity of the geological features in the POS (Figure 22) with the absence of any significant geology in the Calibration Lane images (even at ±12nT). The geological features in the POS are still relatively strong even on a ±100 nT scale. Carrying out an analysis at scales as course as ±100 nT we would fail to detect all but the strongest signals from the largest seeded ordnance.

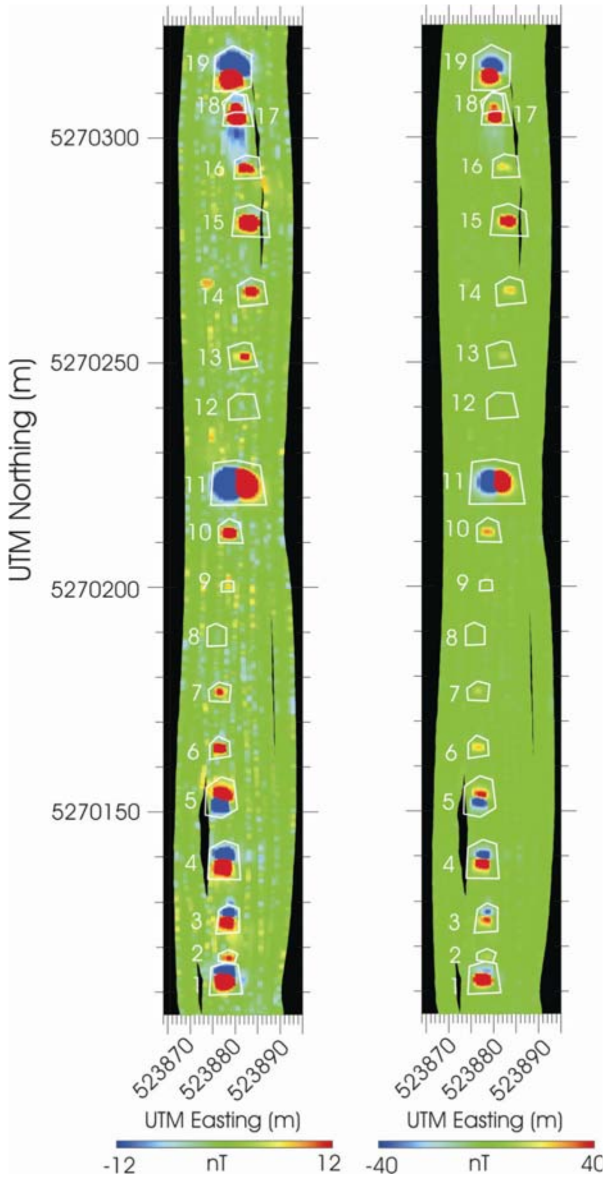

Figure 21. Magnetic anomaly images of the Calibration Lane survey are shown at two sensitivity scales.

As an alternative to working with these geologically-compromised data, we imposed an aggressive low pass filter during preprocessing of the data to suppress the larger (more extensive) geological features. The effect of this filter is shown in the comparison of the left and center panels in Figure 23. We expect the use of this filter to distort the signatures of the larger (more extensive) anomaly signatures. It does, however allow a more effective analysis of the target anomaly signatures that are revealed when the filter is applied. In our analysis of the targets in the POS, we used both the filtered and unfiltered data in a simultaneous joint analysis to arrive at the most inclusive overall target list. We then used the results of the EM survey to try to distinguish between ferrous and geological anomalies on the target list. Based upon our analyses of the targets in the Calibration Line and their comparison with the geologically compromised analysis in the POS, we estimated that up to one-third of the Calibration Lane targets would be undetectable in the POS survey.

The MTA EM system is electronically similar to the Geonics EM-68. The signal measured from the receive coils is partitioned into 26 logarithmically-spaced time windows. During its entire lifetime, the MTA EM system has been plagued by very poor signal-to-noise characteristics. There were major modifications made by Geonics between the Currituck Sound and Ostrich Bay demonstrations. Our static measurements and the lake test measurements indicated that some improvements in the S/N ratio were made during these modifications.

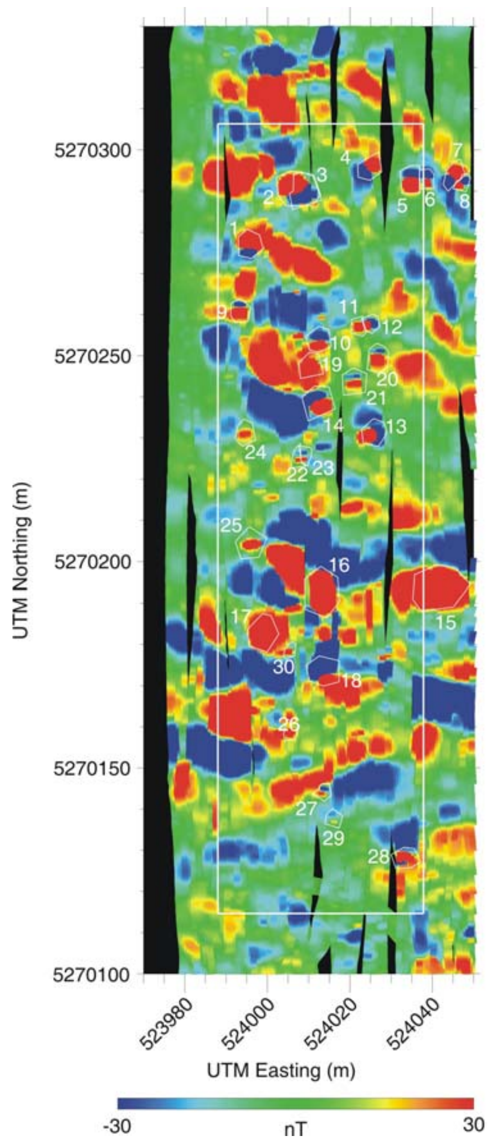

Figure 22. Magnetic anomaly map of the POS.

The initial measurements in Ostrich Bay however, indicated that the S/N level was once again compromised. Additionally, one of the outboard sensors had a continuous spiking noise problem. We attempted to overcome this problem by summing the signals from all the time channels together and raising the zero-level of the analysis window to exclude much of the underlying noise. This allowed detection and analysis of larger targets in the EM data, and more importantly allowed an additional level of discrimination against geological anomalies. For instance, comparative inspection of the magnetometer and EM images in Figure 23 suggests that targets 12, 13, 14, 20, 21, and 24 are likely geological in origin. All three datasets were used to compose the final target list (Table 8) for the POS that we submitted to the Program Office and to NAVFAC Northwest.

The EM system failed completely following the POS survey and we were not able to get it running again during the survey. When the sensor platform was pulled from the Sound following completion of the surveys, the EM interface box was determined to be filled with sea water.

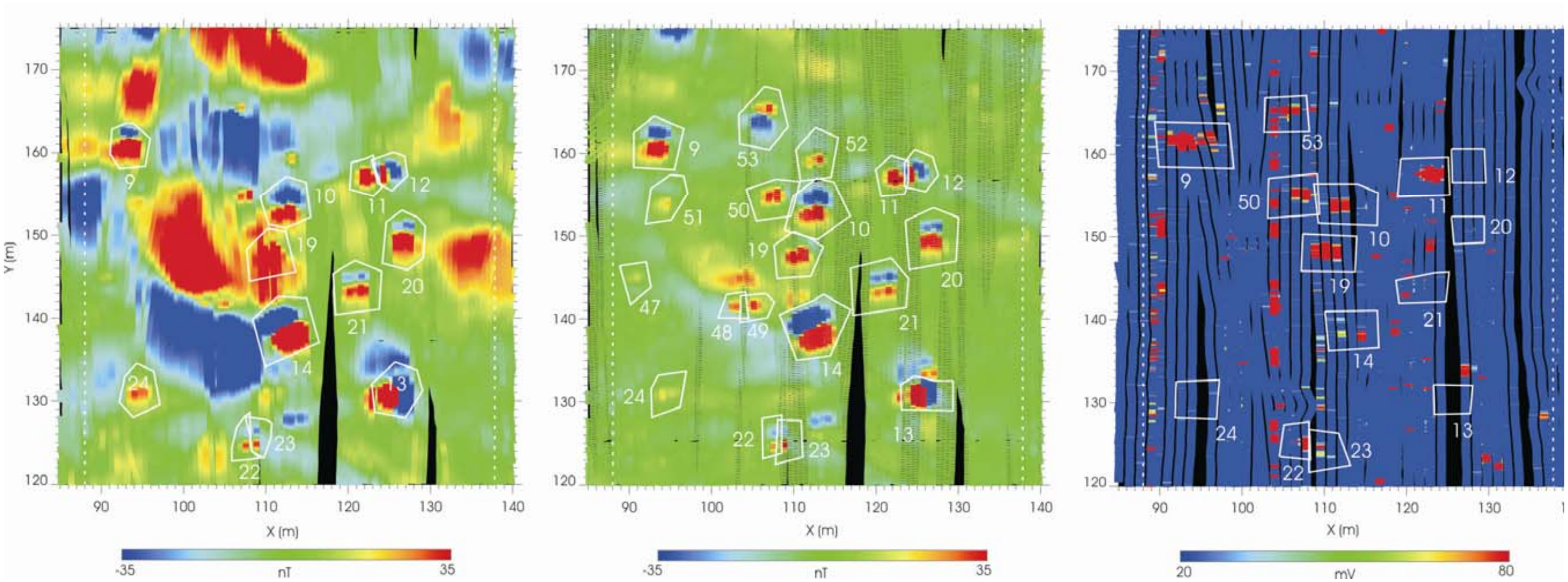

Figure 23. A 1 acre clip from the center of the POS survey is shown. The left panel shows the normally processed dipole image from the magnetometer survey. In the center panel an agressive low pass filter was applied to the data during preprocessing. The right panel shows the same area from the EM survey. The EM survey conditions are discussed in the text.

Table 7. The Analysis of the Calibration Lane Survey

AETC TARGET ANALYSIS									GROUND TRUTH			
Target ID	UTM Easting (m)	UTM Northing (m)	Target Depth (m)	Water Depth (m)	Target Caliber (m)	Moment amp-m^2	Fit Quality	Analyst Comment	UTM Easting (m)	UTM Northing (m)	Burial Depth (in)	Miss Distance (m)
CAL 1	523878.05	5270113.07	0.78	7.10	0.19	3.6873	0.69	Targ 1, Mk81	523878.09	5270112.96	0	0.12
CAL 2	523878.33	5270117.34	0.39	6.89	0.06	0.1444	0.59	Targ 2, BDU33	523878.29	5270117.81	6	0.47
CAL 3	523878.76	5270126.76	0.63	7.14	0.13	1.2307	0.91	Targ3, 155mm Projo	523879.44	5270127.31	2	0.87
CAL 4	523877.91	5270139.23	0.62	7.17	0.17	2.7558	0.87	Targ 4, 155mm Projo	523877.55	5270139.56	3	0.49
CAL 5	523876.95	5270152.86	0.73	7.23	0.16	2.1298	0.90	Targ 5, 76mm wcase	523877.08	5270152.11	1	0.76
CAL 6	523876.56	5270164.29	0.75	7.28	0.09	0.4632	0.80	Targ 6, 5in Rocket WH	523876.45	5270164.27	2	0.11
CAL 7	523876.62	5270176.67	0.50	7.04	0.07	0.1746	0.87	Targ 7, 4.2in Mortar	523876.86	5270176.76	2	0.26
CAL 8			0.58	7.10	0.03	0.0122	0.25	Targ 8, Mk2 Grenade, No See	523877.86	5270188.85	8	
CAL 9	523878.29	5270200.38	0.05	7.32	0.03	0.0158	0.60	Targ 9, 20mm Cluster, No See?	523877.93	5270200.09	3	0.46
CAL 10	523878.46	5270212.34	1.03	7.14	0.12	0.9789	0.84	Targ 10, 5in Rocket	523878.49	5270210.90	1	1.44
CAL 11	523880.68	5270223.75	0.47	7.06	0.29	13.6761	0.86	Targ 11, 81mm Mortar, Massive Remnant Moment	523879.08	5270223.33	5	1.65
CAL 12			1.51	7.46	0.06	0.1085	0.14	Targ 12, Fuze (?), No See			8	
CAL 13	523882.24	5270251.34	1.14	7.51	0.10	0.5755	0.90	Targ 13, 40mm Projo w/?	523881.71	5270251.84	12	0.73
CAL 14	523883.73	5270266.32	1.10	7.30	0.12	1.0442	0.90	Targ 14, 5in RocketWH	523883.19	5270266.25	6	0.54
CAL 15	523883.77	5270281.41	1.05	7.42	0.19	3.8655	0.95	Targ 15, 5in Projo	523883.82	5270281.40	3	0.05
CAL 16	523882.14	5270293.74	0.87	7.51	0.11	0.6396	0.73	Targ 16, 5in Projo	523882.14	5270294.47	12	0.73
CAL 17	523880.15	5270304.54	0.81	7.54	0.18	3.3988	0.87	Targ 17, 6in Projo, Mk 36, Overlaps Targ 18	523879.53	5270304.97	1	0.75
CAL 18	523880.33	5270307.32	0.72	7.57	0.11	0.7739	0.76	Target 18,Gas Generator, Shadowed by Targ 17	523880.25	5270306.59	6	0.73
CAL 19	523879.43	5270314.80	0.64	7.62	0.25	8.4464	0.99	Targ 19, 8in Projo	523879.45	5270314.54	1	0.26
									Average Miss Distance			0.61

Table 8. Target Report for the Survey of the POS

Target ID	UTM Easting (m)	UTM Northing (m)	Burial Depth (m)	Water Depth (m)	Target Diam. (m)	Fit Qual.	Analyst Comments
POS 1	523995.76	5270276.64	0.48	6.04	0.234	0.792	Very Large Target with Remnant Moment
POS 2	524006.67	5270290.73	0.31	5.92	0.278	0.485	Very Large Targ w Remnant Moment, 2nd targ 3 meters east
POS 3	524008.32	5270290.82	0.02	5.93	0.277	0.630	Very Large Target w Remnant Moment, 2nd VL targ 3 m east
POS 4	524024.84	5270295.88	0.16	6.50	0.190	0.929	Very Large Target
POS 5	524035.21	5270292.80	0.09	6.67	0.226	0.950	Very Large Target
POS 6	524038.48	5270293.15	0.11	6.74	0.161	0.789	Med to Large Target 1m East of POS boundary, Not an EM pick
POS 7	524045.48	5270293.52	0.23	7.02	0.241	0.939	Very Large Target w Remnant Moment 8m East of POS
POS 8	524047.17	5270292.17	-0.10	7.04	0.137	0.871	Large Target 8m East of POS
POS 9	523993.43	5270261.46	0.33	6.08	0.161	0.843	Large to Very Large Target
POS 10	524012.83	5270253.85	0.57	4.93	0.203	0.880	Very Large Target
POS 11	524022.27	5270257.28	-0.06	5.10	0.128	0.932	Large Target
POS 12	524024.75	5270257.62	0.01	5.11	0.107	0.674	Medium Mag Target, Not an EM target
POS 13	524025.82	5270231.21	-0.04	4.57	0.220	0.627	Very Large Mag Target w Large Remnant Moment,Not an EM target
POS 14	524012.58	5270239.05	0.33	4.58	0.253	0.768	Very Large Target, Multiple maxima looks like cluster, not an EM target
POS 15	524041.17	5270191.30	4.59	4.36	0.605	0.865	Looks like geology return, East of POS border
POS 16	524011.58	5270191.05	3.46	4.31	0.564	0.770	Too big for bomb, looks like geology, no EM signature
POS 17	524000.02	5270183.41	2.48	4.91	0.302	0.718	Geology Return, Not an EM target
POS 18	524013.68	5270172.86	0.81	4.21	0.341	0.797	Very Large Target, 80% Remnant Moment, no EM signature
POS 19	524010.97	5270247.81	0.74	4.84	0.172	0.582	Looks like geology in mag, good large EM target
POS 20	524026.95	5270250.02	0.49	5.00	0.154	0.769	Large to Very Large Target, not an EM target
POS 21	524021.12	5270244.11	0.28	4.67	0.133	0.720	Medium Mag Target with multiple maxima, no EM signature
POS 22	524007.74	5270225.45	0.58	4.31	0.112	0.688	Small Target
POS 23	524009.06	5270225.08	0.04	4.38	0.074	0.728	Small to Medium Target
POS 24	523994.52	5270231.31	0.99	5.45	0.141	0.755	Looks like geology
POS 25	523995.77	5270204.57	1.67	5.44	0.196	0.471	Likely is geology, no EM signature
POS 26	524005.24	5270159.00	0.02	4.16	0.102	0.819	Small to Medium Target
POS 27	524013.44	5270144.52	-0.15	3.96	0.096	0.825	Medium Target
POS 28	524032.82	5270128.18	0.28	3.48	0.127	0.300	filter 28
POS 29	524016.20	5270137.48	0.07	3.76	0.079	0.889	Possible Medium Target
POS 30	524005.21	5270178.16	-0.26	4.39	0.070	0.668	Small Target hidden in geology
POS 31	524022.01	5270159.23	0.86	3.91	0.104	0.516	Large target, filtered data
POS 32	524002.94	5270158.87	0.28	4.47	0.123	0.817	Large target, filtered data
POS 33	523996.35	5270164.25	0.24	4.87	0.106	0.746	Large target, filtered data
POS 34	523994.48	5270164.06	0.45	4.97	0.127	0.700	Large target, filtered data
POS 35	524028.19	5270177.03	0.41	4.09	0.145	0.618	Very Large target, filtered data
POS 36	524012.88	5270172.41	0.63	4.21	0.276	0.751	Very Large target, filtered data
POS 37	524003.61	5270177.89	-0.25	4.60	0.076	0.845	Medium target, filtered data
POS 38	524006.33	5270189.80	0.61	4.44	0.161	0.681	Very Large target, filtered data
POS 39	524025.40	5270194.46	-0.12	4.26	0.067	0.490	Medium target, filtered data
POS 40	524026.98	5270195.06	-0.19	4.25	0.056	0.546	Small/Medium target, filtered data
POS 41	524031.76	5270208.29	0.84	4.46	0.192	0.697	Very Large target, filtered data
POS 42	524019.66	5270214.09	0.41	4.37	0.111	0.709	Large target, filtered data
POS 43	524018.13	5270213.01	-0.17	4.38	0.086	0.913	Medium/Large target, filtered data
POS 44	524010.90	5270210.38	0.24	4.39	0.118	0.945	Large target, filtered data
POS 45	524001.46	5270215.33	0.35	4.75	0.092	0.856	Large target, filtered data
POS 46	523998.42	5270217.98	0.36	4.97	0.099	0.764	Medium/Large target, filtered data
POS 47	523991.11	5270244.69	0.13	5.98	0.077	0.854	Medium target, filtered data
POS 48	524002.96	5270241.42	-0.02	4.97	0.090	0.754	Large target, filtered data
POS 49	524004.90	5270241.23	0.07	4.80	0.106	0.858	Large target, filtered data
POS 50	524008.16	5270255.16	0.25	4.98	0.116	0.666	Medium/Large target, filtered data
POS 51	523994.52	5270254.64	0.61	5.83	0.114	0.842	Large target, filtered data
POS 52	524012.96	5270259.83	0.21	5.05	0.108	0.803	Medium/Large target, filtered data
POS 53	524006.51	5270264.64	0.13	5.26	0.127	0.708	Large target, filtered data
POS 54	524009.40	5270286.37	1.50	5.81	0.184	0.475	Large target, filtered data
POS 55	524011.15	5270287.58			0.108	0.460	Not Mag Pick, medium EM pick
POS 56	524005.81	5270265.15			0.089	0.530	Not Mag Pick, medium EM pick
POS 57	524007.08	5270255.60			0.110	0.570	Not Mag Pick, medium EM pick
POS 58	524010.01	5270209.46			0.085	0.500	Not Mag Pick, small EM pick
POS 59	524029.53	5270177.34			0.121	0.730	Not a Mag Pick, good medium EM pick

Target size predictions are based upon categories defined in Table 3 of the Marine Geophysical Prove-Out Site Installation. Predicted negative values lie above the sediment interface. Deep target predictions are typical of geological returns.

The POS Survey Results: The POS was originally populated with 72 inert ordnance items and DMM-related objects. These had a similar size distribution to the targets in the Calibration Lane. AETC conducted the demonstration survey during the 3rd and 4th week of June, 2006. Tetra Tech conducted their POS survey in mid October. During this time period, NAVFAC conducted a partial reacquisition of the POS targets in two different studies, one in June the other in late October. In their report,[17] NAVFAC developed multiple types of scoring tables based on only the targets they had reacquired, based upon all 72 targets (with 8 deleted, because they were not verified), and on all 72 original targets. Both the absolute performances (fraction of true positive targets reported) and the relative performances (the same metric comparing Tetra Tech and AETC reporting) were similar for each of the grading schemes. We cite below only the results based upon the entire 72 targets because our survey was conducted a relatively short time after the preparation of the site. One should keep in mind that the strong tidal currents (up to 5 kt) could have easily have moved some of the smaller targets, either before our survey or in the period between our survey and Tetra Tech's survey. It was indicated in the final reacquisition that some of the targets were covered by several tens of cm of silt by the time that Tetra Tech conducted their survey.

Tables 9 and 10 adapted from the NAVFAC report, [17] summarize the target detection performance results on the POS based upon all 72 of the original targets using either a 1 m or a 2 m capture radius for the target declarations. As expected, most of the Very Large targets were correctly identified, about half of the Category 3 (Large) targets were detected, about one-fourth of the Category 2 (Medium) targets were correctly reported; the smaller targets were undetectable. The relatively poor detection efficiency for the medium and smaller sized targets was entirely associated with the geological interferences in this area.

5.4.3 The Ostrich Bay Survey

Figure 18 shows an aerial photograph of the part of Ostrich Bay taken at the time when the NAD was in full operation. All the piers and supporting facilities are labeled in the photograph. As described above, subsequently to the closing of the site, all of the structures in the Bay except Pier II were removed. These actions took place at various times between about 1975 and the mid 1980s.

The survey plan for Ostrich Bay[9] was based upon a North-South grid with adjacent survey lines separated by 4 meters. In practice, the southern end of the grid was truncated at the northern tip of Madrona Pont. The southern extent of the grid extended south of the Navy Property line, excluding areas of increasingly shallow water reported to have a deep silt bottom. The southern shoreline is densely crowded with personal properties and offshore moorings for pleasure boats. South of the (northern) tip of Madrona Point, the Bay has no outlet, and presumably would have been less likely to have had significant Navy marine traffic. Figure 24 shows a top level view of the total survey as a magnetic anomaly image superimposed on an aerial photo of the Bay area.

Table 9. GPO Categories/Scores for GPO Scenario 3 (72 Targets)
Table adapted from Reference 17

Classification	DMM Type	Number Installed	Total	AETC # Found using Rcrit=1m	AETC # Found using Rcrit=2m	TTECI # Found using Rcrit=1m	TTECI # Found using Rcrit=2m
Category 4 Very Large	MK81 Bomb	1	10	8	9	6	8
	8" Projectile	1					
	155mm Projectile	3					
	152mm Projectile	5					
Category 3 Large	5" Projectile	2	21	9	12	6	6
	105mm Projectile	1					
	3" w/Brass	1					
	3" Projectile	16					
	40mm Clip (4)	1					
Category 2 Medium	81mm Mortar	10	21	5	6	3	3
	30mm Cluster (5)	1					
	20mm Cluster (20)	5					
	Scrap (Ammo Can)	5					
Category 1 Small	30mm Projectile	5	20	0	1	1	1
	20mm Projectile	10					
	7.62 Cluster (10)	1					
	Fuze	4					
	Total:	**72**	**72**	**22**	**28**	**16**	**18**

Table 10. Percent of Each Size Category Located (GPO Scenario 3)
Table adapted from Reference 17

DMM Size	Rcrit = 1m		Rcrit = 2m	
	AETC	TTECI	AETC	TTECI
(10) Category 4 (Very Large)	80.0%	60%	90.0%	80.0%
(21) Category 3 (Large)	42.9%	28.6%	57.1%	28.6%
(21) Category 2 (Medium)	23.8%	14.3%	28.6%	14.3%
(20) Category 1 (Small)	0.0%	5.0%	5.0%	5.0%
(72) All Categories	30.6%	22.2%	38.9%	25.0%

The intense geological interferences are apparent on the southeastern edge of the survey; this is the POS survey area. The area southeast of Erland Point (in the center of the Bay) that show data holidays are in the areas of deepest water (with depths >40 ft). In the far northwest area of the survey (north of Erland Point) large unsurveyed areas are apparent. These unsurveyed areas are dry land during most of the tide cycle. We attempted to fill them in during high tide, but did not complete surveying the area. North of Erland Point, there are only two areas with more than sporadic metallic signatures. These are associated with the former Railroad Pier and with the northern Navy property line.

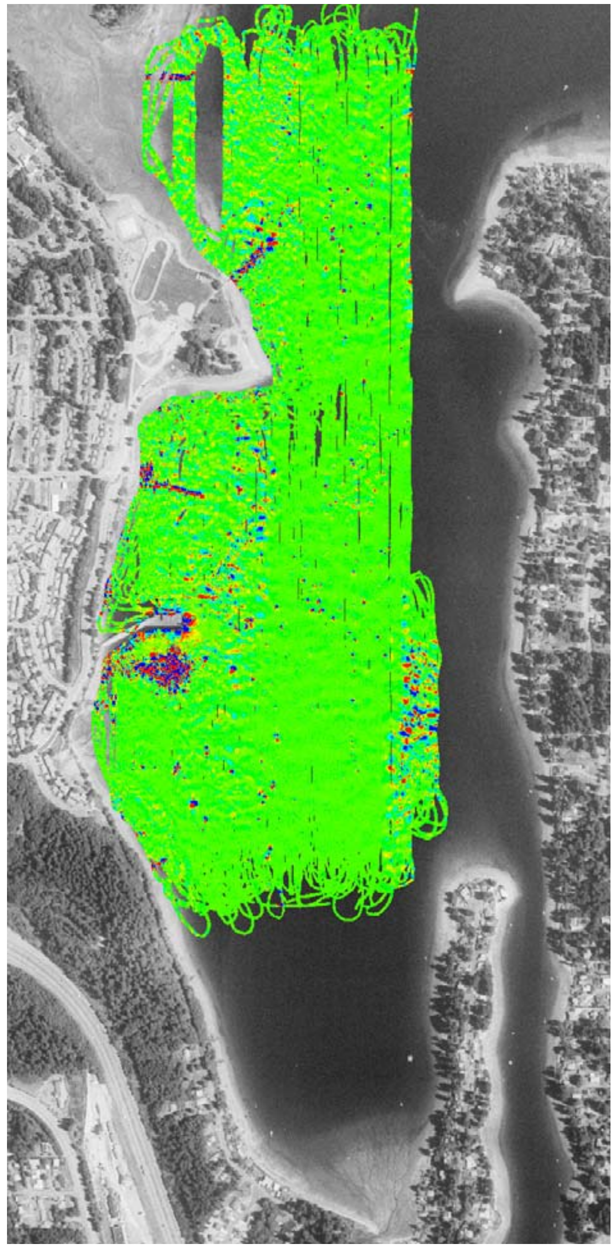

Figure 24. The MTA magnetometer survey is shown superimposed on a recent aerial photograph of Ostrich Bay.

The area of the Bay with the highest density and most extensive contamination of ferrous anomalies encompasses the entire footprint of the former Pier I. This area was not cleaned at the time that the UXO removal action was implemented around Pier II. Each of the areas of high density contamination is discussed individually below.

The Former Railroad Pier: Figure 25 shows a 5.7 acre section of the entire survey, which includes the former Railroad Pier. This area is highly cluttered, note the coarse display scale. The white polygons denote the areas chosen by the analyst for fitting. The target numbers correlate with the features reported in the master target report (see below). The survey area was analyzed in two sections. The area from the western shoreline out to the 4 fathom depth line remains as Navy property. The remainder of the Bay is under control of the state of Washington. Target numbers preceded by the letter N are from the target list that is primarily Navy property. Because the property line is poorly defined and ragged, we extended the cutoff far enough east to be certain that all Navy property was included in the Navy-side analysis. The majority of the targets in Figure 25 are large pieces of ferrous scrap rather than ordnance. Because the railroad cars were reportedly loaded onto and from the barges intact, it is unlikely that ordnance items were accidentally lost into the Bay during these activities. Eight targets were chosen by NAVFAC Northwest for diver investigation. These include N241, N244, N247, N248, N251, N260, N264, and N267. We discuss the Target Report, the Dig List, and the Diver Investigations in a separate section following the presentation of the survey graphics.

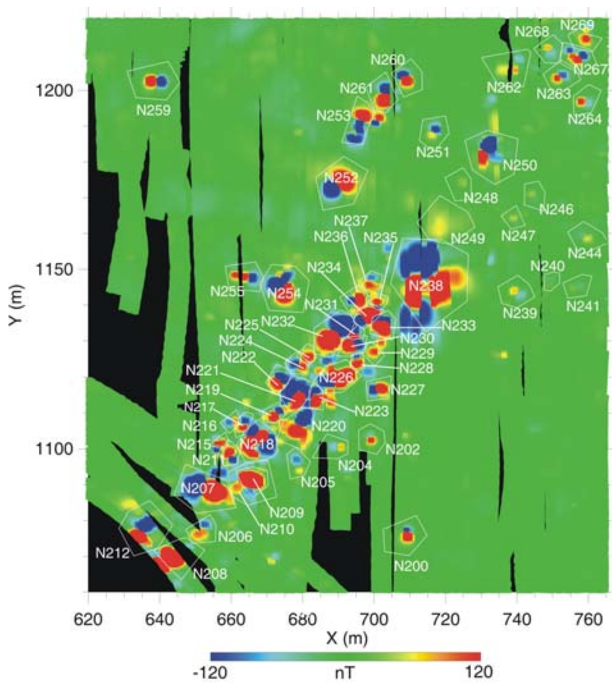

Figure 25. Magnetic anomaly image of the former Railroad Pier area.

The Former Oil Pier: The primary feature associated with the former Oil Pier is a large rectangular area associated with the platform at the end of the pier. This platform area is shown in a screen clip in Figure 26 from the MTADS Data Analysis. The inset in the center of Figure 26 clearly shows about 15 discreet ferrous signatures tightly bunched together within the 12 X 20 m area. Many of the anomalies fit to signatures indicating that they lie above the sediment surface. Figure 27 shows that additional ferrous targets lie along a line stretching west from the platform to the shoreline. The white line on the right side of Figure 27 is the approximate position of the Navy property boundary.

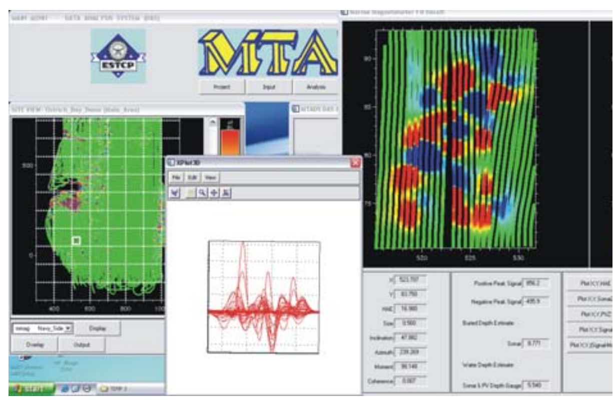

Figure 26. Screen clip from the MTADS DAS analysis of the area at the end of the Oil Pier. The analysis window in the center shows about 15 discrete targets in the 12 X 20 m area.

Only one target in this area was included in the diver investigation list. This was the anomaly at the lower left (southwest) corner of the platform group, which is boxed as N7 in Figure 27. The divers described the target as a large steel box located on the sediment surface, which is wrapped with "lots of cables." Neither the box, nor its contents were further investigated. The group of targets in Figure 27 that are sequentially labeled as N83-N91 all lay along the shoreline. The shoreline in this area is a rocky outcropping that appears to extend out into the water. Many of the anomalies are likely associated with geological returns. A few of the others (N84, N90) may be ferrous objects.

The Utility Line: Figure 28 shows a substantial metallic feature that stretches from the shoreline eastward into the Bay for about 150 meters. Its location is about half way between Pier II and Erland Point. It appears as a depression in the bathymetry image in Figure 19. The feature intersects the shoreline at the point where an East-West road dead ends at the shoreline. This road is visible in Both Figure 18 and 19. We see no evidence in earlier photographs or discussions that the offshore feature was present during the period when the NAD was active. Currently, a substantial shed is located at the waterline where this feature intersects the shore.

Based upon the characteristics of the anomaly signature it could be a storm water drain or a sewer outfall.

This feature was not investigated by divers as part of this project. Only targets N144 and N150 in this image were on the diver investigation list. The white line at the right of Figure 28 is the approximate position of the Navy Property Boundary.

The Mid-Bay: Figure 29 images a 5 hectare area in the center of the Bay, which shows the general level of ferrous contamination typical of the Bay in areas that were not directly associated with on-loading and off-loading activities at the NAD. For perspective, anomalies 76, 77, and 78 are the three northern most targets in the Calibration Line (which include a 6 in and an 8 in projectile). There are a surprisingly large number of medium and large targets scattered across the center of the bay. The density of analyzed targets in this image is about 12 per hectare. Twenty-two of the targets in this image were reported on the recommended dig list that was submitted to NAVFAC. Of these, seven anomalies (126, 138, 144, 150, 156, 312, and 359) were on the diver investigation list.

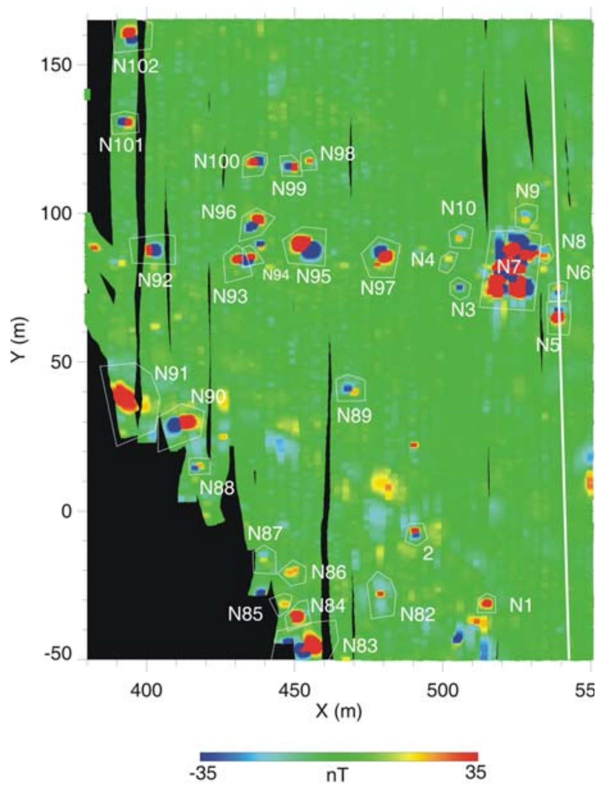

Figure 27. Magnetic anomaly image of the area that includes the Former Oil Pier.

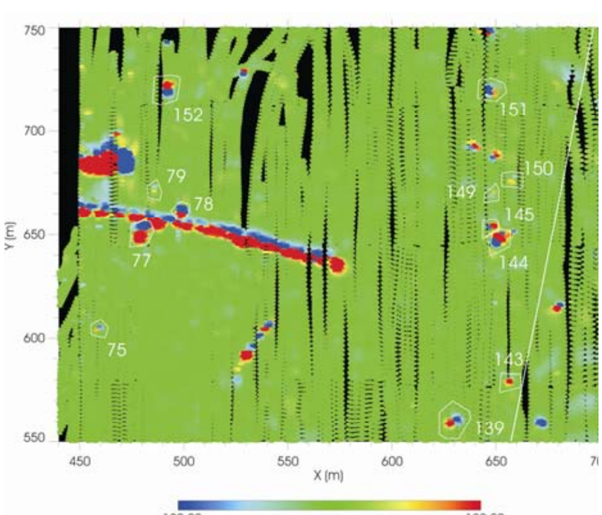

Figure 28. Magnetic anomaly image of a part of the eastern edge of Ostrich Bay that shows a feature referred to as the Utility Line.

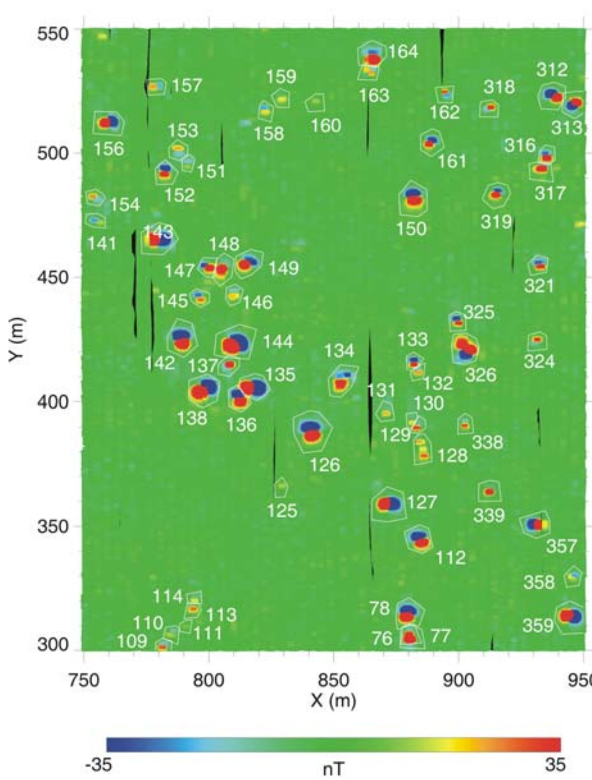

Figure 29. Magnetic anomaly image of a part of the center of Ostrich Bay that shows the distribution of medium and large targets.

Many of the larger targets have a very similar appearance; they are large compact dipole images, they lie very near the surface, and have similar sizes. Of those cited above for investigation, their analyzed sizes are consistent with 6 in to 8 in projectiles. In reality, these large anomalies in the middle of the Bay that were investigated were all non-ordnance related. They are mostly discarded items (engine blocks, large metal scrap, bicycles, etc) or lost items (anchors, anchor chains, cables, ship doors, etc). The actual diver investigations are discussed more fully in a later section of this report.

Pier I and Pier II: Figure 20 (shown earlier in the report) shows a part of the bathymetry map of the Bay around Pier I and II. We hill-shaded the image (from the northwest) to accentuate the abrupt changes in elevation and the other bottom features. The dredge areas adjacent to Pier I were apparently smoothed to the general bottom contour (either when the Pier was removed or perhaps later). The light green contours in the Figure 20 are at 3 ft depth intervals. The dredge cuts around Pier II (particularly on the north side) have 12-15 ft sheer walls. The bottom of the dredge cuts shows features extending above the bottom surface. On the north side of the pier some of these are broken off pilings. Because of the very tight turning areas and short distances, it was impossible to get the sensor platform into the dredge cuts deep enough to do a good survey of the dredge areas. We broke several components from collisions with piling stubs, bottom objects, and the dredge walls while trying.

The disturbed area of the bottom northeast of the corner of Pier II was created when the line of pilings was removed (see Figure 18). Careful examination of the image shows that a few broken off pilings remain in the area. Towards the center of the Bay, the bottom appears to be covered with rocks; examination shows that almost all of the objects in the mid bay do not extend more than 1 ft above the sediment surface. This is not true both north and south of Erland Point where much larger boulders exist.

Figures 30 and 31 show the results of the magnetometry survey around the Pier I and Pier II at two different display scales. In the left image the approximate footprints of the Piers have been superimposed for reference. The area to the north and east of Pier II was not well surveyed for the reasons described above. The area immediately east of the end of Pier II was also not surveyed well because the sheer north dredge wall extends well beyond the end of the pier, see Figure 20.

This entire area is extremely heavily cluttered with small, medium, and large ferrous anomalies. The area within the dredge cut around Pier II was partially cleared of ordnance more than 25 years ago. Unfortunately, the non-ordnance items that were discovered were left lying in the dredge cut. We have analyzed some objects that could be reasonably isolated in this area primarily just to provide a reference for the size of the larger objects either buried or lying on the surface. Reportedly, the metallic objects (ordnance or otherwise were not cleared from the Pier I area when the Pier was removed. Presumably, the dredge cuts around Pier I were filled and smoothed by pushing around the bottom sediments that still contained the metallic clutter (ordnance and otherwise). This is supported by our analysis that shows that much of the metallic clutter in the area of Pier I lies on or near the surface.

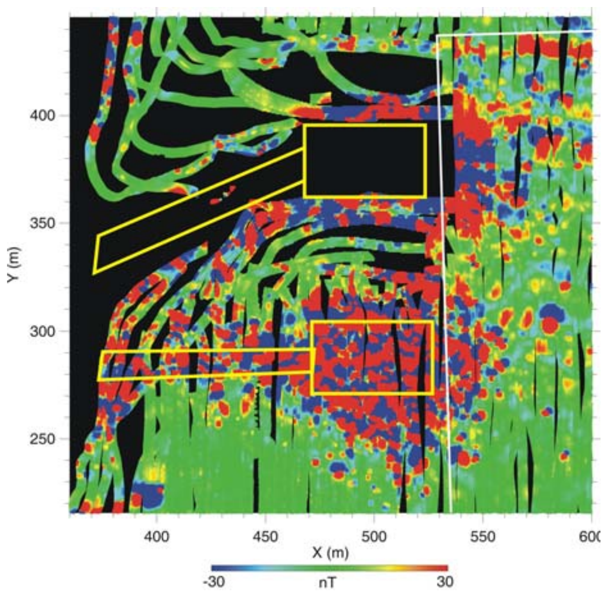

Figure 29. Magnetic anomaly image of the Pier I and II area at ±30 nT scale.

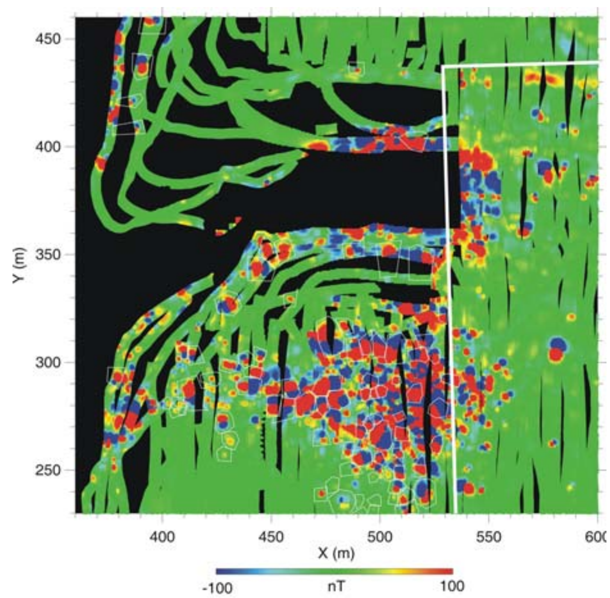

Figure 30. Magnetic anomaly image of the Pier I and II area at ±100 nT scale.

The anomalies that we analyzed and reported around the edges of the clutter field around each pier could be isolated and removed in a recovery action. However, targets in the dense part of the clutter field, if they were retrieved by divers, would not have a high probability of recovering the target that was analyzed and reported on the dig list. To clean the areas around these piers will require at least two cycles of clearance and resurvey. The large metallic objects, and all other metallic objects that protrude from the surface must be removed before an effective survey and clearance of the pier areas can be undertaken. This approach is no different than having to conduct a surface clearance of the bull's eye areas of land ranges before an effective survey and clearance operation can be undertaken.

5.5 Validation

Validation of the quality of the MTA Demonstration Survey was a two part process. The first step was the survey, analysis, reporting, performance grading of the MTA survey of the POS. This was described and reported in Section 5.5.2 of this report, see Tables 9 and 10. We were not aware of the specific performance on the POS until more than a year after all our work products had been submitted to NAVFAC.

The second component of the validation process was built around a diver investigation of 100 surveyed anomalies. We will specifically describe in Chapter 6 of this report the data products that were submitted to NAVFAC and the techniques that were used to develop them. In general, we analyzed all anomalies from our survey data. All those that might possible conform to the characteristics of ordnance items (and additionally, many others) were included in our complete Target Report. We graded all analyzed targets in the Report as to their probability of being intact ordnance. At the request of NAVFAC, we submitted a list of somewhat more than 100 targets that we recommended for investigation. This was labeled as our recommended Dig List. These spreadsheet products are included in the Appendix F of this report.

NAVFAC, working in cooperation with the EPA Region 10 representative took our Target List and our recommended Dig List and independently developed their final list of 108 targets for diver intrusive investigation. The criteria for this selection process are also included in Chapter 6 of this report, as is an analysis of the results of the intrusive diver investigations.

6.0 DATA ANALYSIS AND SURVEY WORK PRODUCTS

The initial Work Products of the Demonstration were the analysis and reporting of the MTA survey results from the Calibration Lane and the POS. The data processing, target analysis, and preparation of the target lists and results were completed in real time following the surveys on June 18 and 19. The remainder of this chapter describes the workflow and processes used to accomplish these tasks. The POS analysis results were presented orally to NAVFAC (and EPA) in a briefing and delivered in written form to NAVFAC and the ESTCP Program Office on 22 June 2006. The ground truth for the POS was unknown to us until the After Action Report[17] was released in Final Draft in April 2007. The results of our POS survey analysis and comparisons with the ground truth were presented and described in Section 2.3 of this report.

The target analysis for the entire survey was completed shortly after the survey and the work products described below were submitted to the Program Office and to NAVFAC to support the intrusive diver investigations. Details of this process are provided in Section 6.5.

6.1 Survey Data Preprocessing

Raw survey data were processed using standard Geosoft montaj® utilities and were available for inspection the next morning following the prior day's survey. The techniques that are used to preprocess the raw data are equivalent to those that we have used for over a decade to prepare data from other marine surveys, from helicopter magnetometer array surveys, and from towed vehicular surveys. Data from outside the designated survey area are censured, as are data from turn-arounds and periods when the platform is not moving. The individual sensor baseline levels are correlated and a down-the-track smoothing filter is applied to the data. The data are leveled to a common null point (each time datasets are combined) and finally, the data are interpolated onto a (previously established) grid for loading into the target (anomaly) analysis software. Several other quality control checks are also applied each time a dataset is preprocessed. These include confirming that the appropriate layback values (associated with each cable deployment) are being used, that the angular encoder, platform yaw, and platform altitude values are correct and consistent. These are evaluated primarily by using data image inspections.

"Course-Over-Ground" plots and dipole image presentations of the data are prepared, which allowed additional quality control evaluations to be made. Additional Track Files are prepared (as required) for insertion into the Pilot/Survey Guidance display to allow resurvey of areas that were missed or areas where survey data quality were not acceptable.

Each day the master survey data file was updated to include all accepted survey data. The files were formatted for input to the MTADS DAS, at which time individual target analyses could begin. In this operation, separate master survey files were maintained for the POS survey, the Calibration Lane survey, and EM surveys. All remaining magnetometry data were incorporated into a single master MTADS DAS data file. A landmark file was created from approximate coordinate positions tracking the Navy Property Line. This landmark file appears as a white demarcation line in MTADS DAS displays of the data.

6.2 Target Selection and Target Analysis

The target analyses were carried out as two separate processes; one for the anomalies within the Navy Property boundary and the second in areas of the Bay beyond the Navy Property boundary. The same evaluation criteria were applied with each dataset.

The MTADS DAS (version adapted for MTA analyses) was used for all target analyses in this demonstration. The MTADS DAS target fitting routine carries out an iterative fit of the sensor information in a data clip (defined by the analyst to encompass the visible anomaly) to a dipole signature. The input data to the fitting routine are based upon three dimensional coordinates (the UTM coordinates and HAE of each sensor reading) and the value of the sensor reading. This allows overlapping data from multiple passes of the sensor array (at differing heights above the bottom) to be appropriately incorporated. The fitting routine is fully three dimensional and the output of the fitting process reports the coordinate position of the center of the object (UTM coordinates and HAE), the apparent induced magnetic moment and the inclination and azimuth of the induced dipole, the fit quality of the dipole approximation, and a derived predicted caliber of the target (assuming a cylindrical shape with a length to diameter ratio of 4). Additionally, the maximum and minimum signal strength and the water depth at the target position are reported.

Figure 32 shows a screen clip from the MTADS DAS analysis of an individual target (Anomaly 309) in this survey. The discussion below describes the analysis workflow and some of the analysis images, tools, and routines available to the analyst for the fitting process. The Site View window (partially shown on the upper left) shows the entire survey area with the 30 X 30 m analysis area outlined in white. The analysis window (partially shown in the center) is used by the analyst to select individual targets for analysis. In this case the analyst has boxed an area by using the computer mouse to draw a polygon surrounding the anomaly. The position and display scale of any of the images shown in the figure can be changed by the analyst. The data bounded by the polygon are submitted to the analysis algorithm to carry out the iterative fit described in the previous paragraph. The fit window (half of which is shown on the right of Figure 32) shows plots of the data submitted for analysis and the best dipole fit to that data (The fit image lies to the right of the image that is shown in Figure 32). The image in the Fit Window shows that this anomaly has data contributed from parts of four passes by the sensor platform. If the analyst notes that there are contributions from an additional anomaly in the Fit Data, using the computer mouse, he can delete the parts of individual sensor tracks from the analysis, and then rerun the analysis. Alternatively, if the analyst notes that there are widespread geologic features that contribute a varying interference offset to all the data displayed in the Fit Window, he can invoke a leveling tool that will level all the data in the display to the best flat background level. The fit can then be rerun. Following the iterative fit, which usually takes about one second, the Fit Values are displayed on the left side of the Fit Window. In the center panel of the displayed area of the fit window information is provided about the signal parameters, the (raw) estimated depth, and the water depth. The estimated burial depth must be later corrected for the (variable) depth of the sonar sensor below the water surface. In this case, it was 0.5 m, so the predicted burial depth is only about 1.6 cm. On the lower right of the Fit Window display are radio buttons for several analysis options available to the analyst. These are described below.

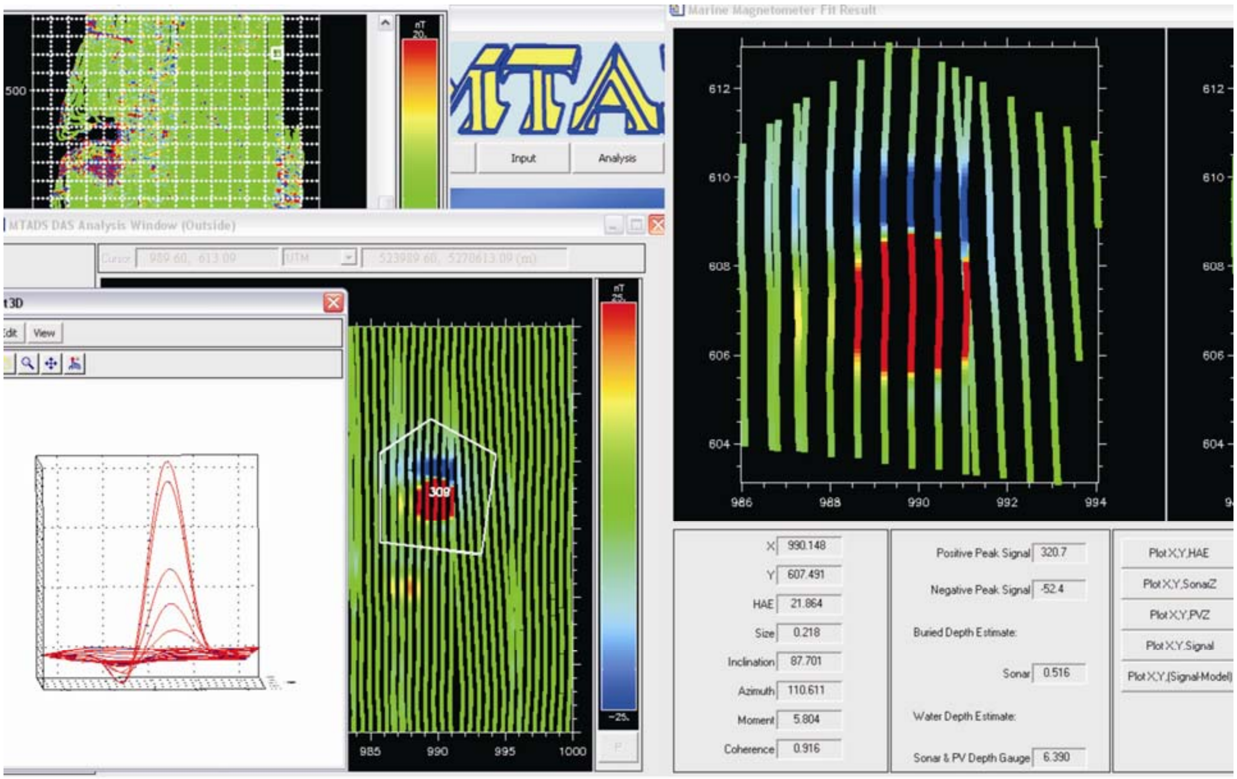

Figure 32. A screen clip from the MTADS DAS analysis of Target 309 is shown. See the text for a discussion of the individual components of the image.

The analyst has several additional tools to help him make decisions about an individual target and the fitting process that has taken place. These tools include: (1) a 3-dimensional presentation of the altitude above the bottom for each sensor track for the various platform passes that contributed to the analysis data; (2) a 3-dimensional presentation of the individual sensor readings along the tracks created by the platform passes contributing to the analysis data; and (3) a 3-dimensional plot of the residuals resulting from subtracting the dipole fit from the data entered into the analysis. The altitude plot can be used to quickly determine the altitude above the bottom of the sensor platform in the passes that contributed to the data clip and to show whether the platform was in a roll attitude during one of the passes. The plot of the sensor data can reveal many things such as whether there were multiple objects contributing to the signal, whether there was clutter around (or on top of) the primary object that confused the dipole fit, or whether there were significant remnant moment contributions to the signature. The image on the lower left of Figure 32 shows an example of the use of the (Plot XY Signal) analysis tool. In this plot of the site window the analyst has rotated the image so that we are looking cross track from left to right. The data are very clean, showing only a single major anomaly with no significant clutter and a flat background. Once he is satisfied with the overall fit process, the analyst then has the option to type in a narrative comment and accept the fit as part of the record.

Following the initial fitting process, additional recorded sensor data from the vessel and the sensor platform are used to reduce the HAE value of the target fit to a burial depth of the object below the sediment surface. Before each target fit is logged, the analyst has the opportunity to record narrative observations relating to the target and a subjective numerical target classification approximation. In this demonstration, targets were classified on a four point scale:

- 1 denotes a target with the highest probability of being ordnance,
- 2 denotes a target that deviates from an excellent dipole fit, but still has a good probability of being ordnance (perhaps it is located in a mildly cluttered environment),
- 3 denotes an anomaly signature that strongly deviates from a simple ordnance dipole; it is unlikely to be ordnance, but not conclusively so (it may lie in a highly cluttered field, or be mixed up with an overlapping signature from other nearby objects, and
- 4 is an analyst's declaration that the anomaly is conclusively not an ordnance item.

6.3 Parameter Estimates

Based upon the list of ordnance recovered from the UXO clearance around Pier II (Table 3) and on information provided about the targets included in the Calibration Lane (Table 7) and presumably also in the POS the ordnance size limits of interest varied from five different types of handgun and rifle cartridges to 1000 lb bombs and 16 in projectiles. As we have illustrated earlier in the report, the individual examples of all the smaller cartridges, grenades, fuzes, etc are below the detection limit for the MTA (with or without) geological interference effects considered. Therefore, there are basically no threshold size limits that can be applied to filter targets from the list of potential ordnance items. We have extensively discussed in Section 6.2 the various parameter, display, analysis, and fitting options available to the data analyst for target fitting.

6.4 Classifier and Training

Classification of anomalies by probability of their being ordnance and by likely identity (size) was not done by any type of software developed filter for data analysis in this demonstration. As extensively described above, a single human analyst working with the MTADS DAS software utility analyzed all data and classified all targets using the parameters generated from the MTADS DAS anomaly fits, the additional available MTADS DAS analysis tools described above, and subjective decisions based on decades of experience made and recorded the target classification decisions. The 1-4 scale (described above) was used for classifying the probability of analyzed targets being UXO.

Subsequent to our submission of our data products to NAVFAC (see Section 6.5) they asked us to reclassify our analyzed targets based upon the scheme shown in Table 9. Table 9 was extracted from Ref 17, which was not available to us for more than a year after completion of the survey. At any rate, this size classification scheme was used to rank probable target size and is the one that ultimately was used by NAVFAC and EPA in developing the Diver Investigation List from our Target Lists and Dig Lists, See Section 6.5.

6.5 Survey Work Products

In the Ostrich Bay magnetometry survey many strong anomaly signatures were not analyzed (or at least were not reported as part of the Target Report). These included massively big objects that could not possibly be individual ordnance items, extended objects (likely pipes, cables, anchor chains, etc), and areas adjacent to piers that were so crowded with anomaly returns that they could not be sufficiently isolated for a meaningful analysis.

The Target Report for the Navy Property contained 358 entries; the corresponding Target Report for the remainder of the Bay contained 273 targets. The Target Reports are included in Appendix F with file names of "Bay Side Target Report" and Navy Side Target Report."

We were encouraged to also prepare reports that included targets that we recommended for intrusive investigation by the divers. We submitted separate lists for each of the analyses datasets (Navy Side and Bay Side). It was our understanding that the Navy intended to investigate about 100 targets. Our recommended lists are included in Appendix F with the file names of "Bay Side Dig List" and Navy Side Dig List." The Navy Property dig list contained 65 entries and the Bay Side list contained 58 entries.

Following the submission of our inclusive Target Lists and the recommended dig lists, NAVFAC, working in conjunction with the EPA regulator, developed a final Target Investigation List for the divers to intrusively investigate. The Navy Investigation List contained approximately half of our recommended "Dig List" targets and about half from our other Target Lists that did not appear on our Dig Lists. The Navy/EPA investigation list emphasized inclusion of smaller targets (independent of our classification scheme) presumably on the assumption that individual ordnance items were likely to be smaller (on the average) than the larger targets that dominated our submitted Dig Lists. The Navy/EPA list also included some targets from all areas of the survey. Our dig lists contained very few targets from the south end of the Bay or from the Bay north of Erland Point (except for the Railroad Pier).

Figure 33 shows the locations and distribution of targets that were chosen by NAVFAC/EPA for intrusive investigation. The targets appear as red (or yellow) circles overlaying the bathymetric map of the Bay. Insets show expanded views of the former Oil Pier, Pier I, the Railroad Pier, and Pier II.

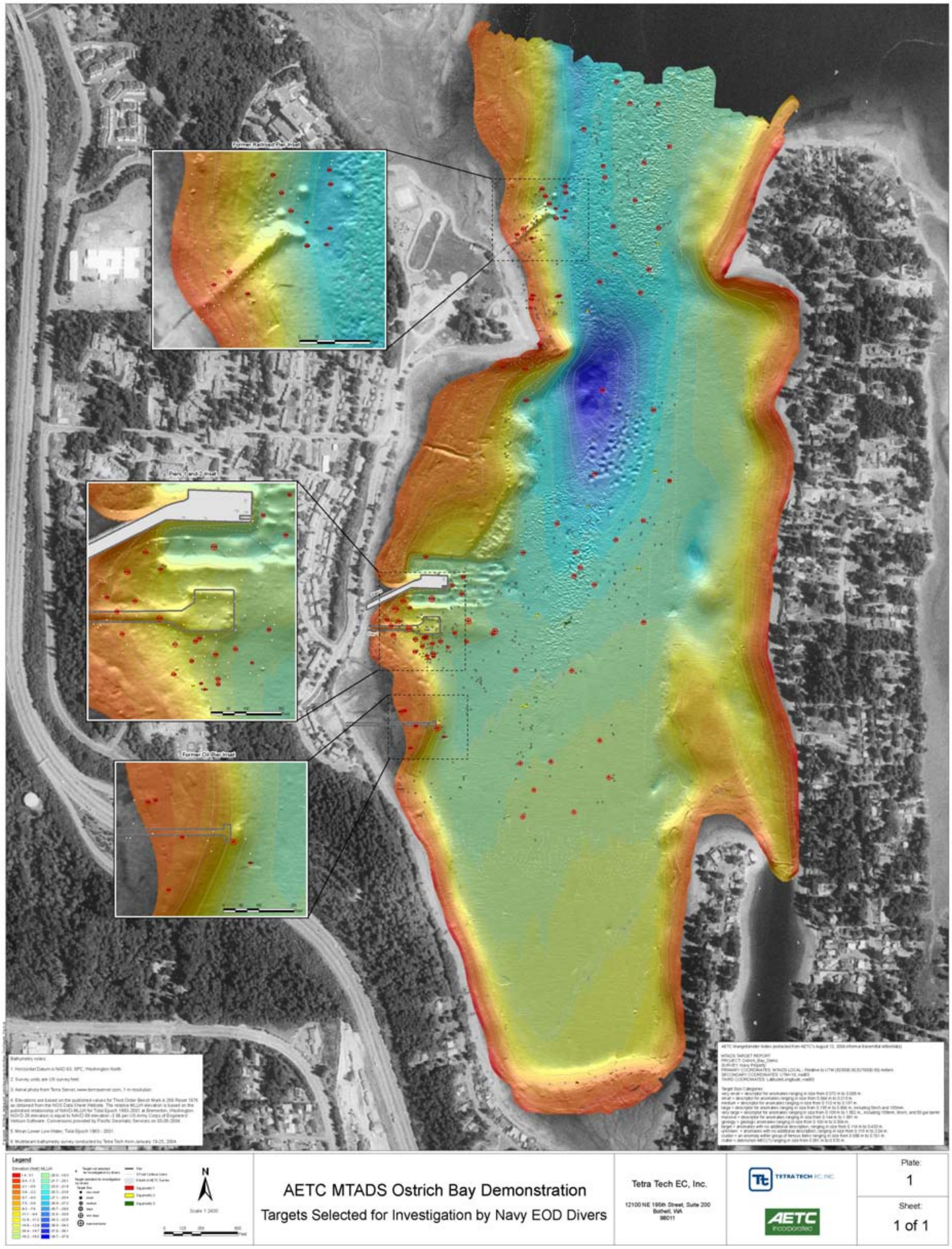

Figure 33. The targets chosen for diver intrusive investigation are shown.

7.0 PERFORMANCE ASSESSMENT

The quantitative and qualitative performance objectives are enumerated in Tables 1 and 2. In Table 1 a specific descriptive response has been entered describing the performance relating to the individual objective statements. The performance-related narrative relating to objectives involving responses to equipment failures, breakdowns, and repair issues was addressed in Section 3.1.

Section 3.2 provides narrative specifically relating to the performance of the EMI array in the sensor platform and the associated electronics and software on the tow vessel. The ultimate resolution of these issues (within the context of this specific project) is also described in Section 3.2.

The performance-related issues involving the objectives associated with system mobilization, deployment, and GPS/platform positioning objectives are discussed in Section 3.3. Mobilization issues were complicated because we had to carry out the initial stage of the operation in Seattle (more than 20 miles from the work site) because this was the location of the nearest heavy boat lift to remove the boat, trailer, and sensor platform from the trailer truck that transported it to the west coast. Fortunately, there was a reasonable access for driving the boat through Puget Sound to the Silverdale public marina where the entire system was assembled, launched and driven 6 miles (towing the sensor platform) to the work site where it was moored throughout the deployment.

All the equipment component breakdowns during the demonstration (actuator cables, GPS antenna, and marine magnetometer malfunction) were associated with the trip on the truck to the west coast. Each of these failures was addressed in Silverdale where the sensor platform could be put into the water for testing, and pulled from the water for troubleshooting. The cable was replaced with a spare from stock. A GPS antenna replacement was ordered for overnight delivery and the magnetometer problem was corrected by performing repairs on the data acquisition software. The only other equipment failures during the survey operations (except for the EM sensor interface module) were associated with sensor platform collisions with bottom structure, broken off pilings, or other obstructions. These were repaired with new cables or sacrificial “cow catchers” from spare stocks. No significant time was lost to make these repairs.

Overnight processing of the data allowed next day fill in of missed areas or areas where the data quality was questionable. With two exceptions, survey coverage was effectively complete for areas that were surveyed. There were significant missed areas associated with surveying the dredge cuts around Pier II. The MTA system is not designed to abruptly climb into or out of the ditches with 12-15 ft high sheer walls. Additionally, there were a few areas associated with the small region southeast of Erland Point with incomplete survey coverage because the water depths were greater than 40 ft.

One of the primary objective criteria addressed the location accuracy of the MTA system. The two options for evaluating the location accuracy of our target predictions are to compare them to the locations of identified targets in the POS and the ability of the diver investigations to locate and identify the targets in our Dig Lists. In retrospect, each of these approaches is inappropriate. The POS target positioning accuracy goal was claimed to be 1 meter. The ability of the EOD divers to reacquire targets in deep water is undetermined, but is likely no better than ± 2 meters. The historical accuracy of the MTA for determining target positions is accurate to ~25cm with the magnetometer array and ~35cm with the EM array. This is effectively independent of water depth.

7.1 Diver Intrusive Investigations

One of the objectives of this demonstration involved creation of the survey work products to support diver intrusive investigations of a sampling of targets representative of the site. We have described the data analysis process and the creation of the Target Lists from the analysis and creation of the recommended "Dig Lists" for investigation in Chapter 6. We have also described how these work products were adapted by NAVFAC and EPA to prepare the final Diver Investigation List of 108 targets.

The intrusive investigations were carried out by the Bangor Naval EOD Detachment, Figure 33. They were provided the Intrusive Investigation List prepared by NAVFAC, which contained 108 targets. They used the same control point on Pier I that we used for the survey and used Trimble GPS equipment equivalent to ours for their target reacquisition operations. They used a large craft to support the target reacquisition and the dive operations, Figure 34. Targets were reacquired by driving the vessel slowly under direction of the GPS unit and dropping a weight attached to a buoy approximately on the anomaly position. The diver followed the buoy line to the weight and used the metal locater (Figure 33) to isolate the specific target position. Visibility was relatively good (up to 5 ft in shallow water), which helped the diver in his investigations.

The Navy Det filled out columns in the

Figure 34. The Bangor EOD Detachment.

Figure 35. This is the vessel that supported the Bangor Det divers.

NAVFAC Investigation List Spreadsheet with a narrative description of their observations for each individual target investigation. Additionally, they inserted photographs or X-Ray images into the spreadsheet for objects that they retrieved. The spreadsheet completed by the Det is included as Appendix G to this report. The file has the title "Bangor Det Completed Dig Report.xls."

7.2 Analysis of the Diver Investigations

NAVFAC provided us with the Investigation Report spreadsheet and asked us to provide an analysis and specific comments. We reinvestigated each target/anomaly in the spreadsheet with the Det comments and provided an additional comment based upon our reanalysis. This spreadsheet has been condensed (unnecessary columns are hidden) and is presented below as Table 11.

Of the 108 targets in Table 11 submitted for investigation, 6 did not contain any information from the Det and were therefore presumably not investigated. There were 8 targets recovered that were declared as MEC or were MEC-related. Seven of these were around Pier 1; one MEC target was associated with the Railroad Pier. These are printed in red font in Table 11.

From our re-analyses of the investigated targets, we declared that the information provided by the divers described an object that was consistent with the size and description of the analyzed target in the 64 of the 102 reported investigations. In 7 instances the diver-reported information was insufficient to definitely correlate the investigation report with the analyzed targets.

In 30 of the diver-reported target descriptions we concluded that the described target was either much too small or much too large to be the described target, or that the diver had failed to find any target at the reported position.

In several instances, the diver-reported investigations described (recovered) non-ferrous targets. These may have resulted from the use of a frequency-domain all-metals detector by the diver, or the diver having visually spotted a brass MEC item, resulting in his concluding the search at that point. Seven of the 8 MEC recoveries were of items that are undetectable by the MTA magnetometers. Several of the diver mistakes were probably associated with searching for targets in the Pier I and RR Pier areas where the underlying target and clutter densities were very high. Many of the 30 inconsistent diver reports (described above), including all of the declared no finds, should have been reinvestigated as a result of QA/QC evaluations.

Table 11. Analysis of the Bangor Det Diver Investigation Report

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
East End of Pier I & II	107	523581.65	5270306.02	8.21	0.623	0.79	Giant target east of Pier 1	too big for ordnance, dig	large angle iron on bottom surface - massive target	Recovery Consistent with Anomaly and Analysis
East End of Pier I & II	332	523546.49	5270378.24	8.73	0.229	0.01	large object east of Pier II	Dig IT,	scrap metal, 6-12" BBS	Insufficient info to evaluate
East End of Pier I & II	334	523568.69	5270396.66	8.05	0.216	0.03	large target east of Pier II	on surface, dig	12" flash Tube **(MEC scrap)**	Recovered object smaller than analyzed target
East End of Pier I & II	335	523566.51	5270361.95	8.92	0.400	0.45	very large object east of Pier II, dig	Dig IT,	5" projectile unfired, 4" BBS **(MEC)**	Recovered object smaller than analyzed target
East End of Pier I & II	365	523554.34	5270280.00	8.44	0.243	0.50	large target east of Pier I	edge of Pier I, dig	large piece of round steel, bent like a "U" 8' long, buried 6" BBS	Recovery Consistent with Anomaly and Analysis
East End of Pier I & II	371	523579.49	5270262.72	8.78	0.177	-0.20	large target east of Pier 1	on surface, dig	shell casings, small, 20 or more items, all buried BBS, brought up 1- 20mm casing, **1- 50 cal casing (MEC, blank w/primer)**	Brass recovery inconsistent with a mag anomaly, wrong relocation sensor used.
East End of Pier I & II	374	523540.40	5270251.11	8.48	0.179	0.10	medium target, SE of Pier I	corner of Pier I, shallow, dig	50 cal round, 6" BBS **(MEC)**	Brass recovery inconsistent with a mag anomaly, wrong relocation sensor used.
Mid-Bay Mystery Targets (MBMT)	26	523697.70	5270016.31	5.79	0.231	0.21	target size=8in projo	Mid-Bay Mystery Target MBMT, dig	2 ft x 2 ft by 6" thick steel plate, 3" below bottom surface (BBS)	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	89	523682.87	5270207.15	8.07	0.286	0.60	size of 8in projo	MBMT, 2ft deep, dig	large anchor chain, 2' loop with both ends in bottom, large links, 3" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	126	523841.12	5270388.59	7.15	0.315	0.29	very big target, dig	MBMT, dig	anchor chain, samll pocket knife, 1 ft BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	138	523798.34	5270405.39	6.99	0.382	0.74	Very large target, dig it	MBMT, dig	5 ft pile of junk, metal of various sizes, on the surface and buried as well	Recovery may not be consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	140	523690.78	5270450.50	6.65	0.264	0.53	size=8in projo	MBMT, dig	definite contact, too deep to dig, over 36" BBS	Insufficient info to evaluate
Mid-Bay Mystery Targets (MBMT)	144	523810.99	5270423.50	8.00	0.374	0.58	Very large target, 2nd smaller target 8 m to S	MBMT, dig	derelict fishing gear, cable with rings on it, on surface and 1-2" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	150	523882.17	5270482.76	6.70	0.264	0.40	size=8in projo	MBMT, dig	3' x 3' block of steel, 6" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	156	523759.93	5270512.76	9.02	0.223	-0.03	size=8in projo, 1	MBMT, dig	3" diameter pipe, 6' long, 4-12" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	175	523834.47	5270617.84	8.71	0.274	0.60	size=8in projo	MBMT, dig	large chunk of concrete with rebar, 6"-12" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	298	523953.32	5270753.02	7.61	0.203	-0.01	very large target, dig	MBMT, dig	large flat piece of steel, 18" BBS	Recovery Consistent with Anomaly and Analysis

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
Mid-Bay Mystery Targets (MBMT)	309	523990.15	5270607.49	6.39	0.218	-0.08	large target, dig this	MBMT, dig	large engine block on surface	The recovered object appears to be larger than the anomaly, maybe the engine block is aluminum
Mid-Bay Mystery Targets (MBMT)	312	523938.36	5270523.43	6.17	0.237	0.32	large target, dig this	MBMT, dig	large piece of cable, 4" BBS	Recovery Consistent with Anomaly and Analysis
Mid-Bay Mystery Targets (MBMT)	359	523945.05	5270314.27	5.44	0.294	0.13	very large target, dig it	MBMT, dig	possible steel ship door, 8' long, 3.5' widw, flat with bolts on edges, position lying flat, 6" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	3	523705.86	5269905.38	5.95	0.402	1.06	Very large target, interferring target 5m NNE	too deep to dig	6 ft piece of heavy steel, rounded pipe, 16" in the mud	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	6	523811.55	5269918.06	6.17	0.125	0.45	Good target, 105/155mm	far south area, 2 ft deep, ?	no find, very deep mud	Diver missed Anomaly
non-Navy Propery non-AETC Selected for Dig	21	523882.16	5269991.86	4.71	0.119	0.38	target size = 105/155m	far south area, 1 ft deep, ?	pot (enamel on metal) buried 6" below bottom surface	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	49	523698.53	5270132.67	6.10	0.115	0.22	small target			?
non-Navy Propery non-AETC Selected for Dig	50	523708.04	5270136.81	6.47	0.107	0.14	small target			?
non-Navy Propery non-AETC Selected for Dig	93	523799.17	5270209.91	5.96	0.177	0.33	size=155mm,other targets 5m to SE	midbay 1 ft deep, ?	pipe, similar to plumbing steel or copper, lots of it, 0-6" BBS	Insufficient info to evaluate
non-Navy Propery non-AETC Selected for Dig	110	523785.16	5270307.21	6.43	0.103	0.01	small target		round steel rim shaped target, 6" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	111	523790.73	5270309.67	6.15	0.072	0.32	very small target		6" diameter wheel, 6" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	115	523724.00	5270323.76	6.55	0.113	0.87	small target		debris field, 0-6" BBS	The depth and size of the recovered clutter object is inconsistent with the dig sheet
non-Navy Propery non-AETC Selected for Dig	166	523822.64	5270550.81	8.03	0.085	0.15	very small target			?
non-Navy Propery non-AETC Selected for Dig	190	523846.03	5270790.79	11.33	0.201	-0.67	size=8in projo	very deep water, dig?	small outboard motor, 0" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	199	523810.55	5270953.65	9.87	0.083	0.04	small object		debris, beer cans, scrap metal, on surface to 12" BBS	Recovery Consistent with Anomaly and Analysis

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
non-Navy Propery non-AETC Selected for Dig	202	523834.62	5271014.64	8.77	0.217	0.36	size=8in	?	3' x 3' x 1" steel plate, 4" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	205	523864.79	5271073.34	8.62	0.253	0.95	size=8in	MBMT too deep	2" diameter pipe, 7' long, 12" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	206	523858.82	5271130.42	7.40	0.372	-0.04	Very large target	MBMT, north of erland, ?	1" diameter pipe, 24" long, 2-4" BBS	Recovery much smaller than Anomaly
non-Navy Propery non-AETC Selected for Dig	214	523838.44	5271231.28	7.67	0.288	0.53	size=8i projo	MBMT, north of erland, ?	debris field of plumbing pipe, 2-5" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	221	523834.82	5271254.18	8.10	0.325	0.64	too large for ordnance, check it out	too deep to dig	two separate targets; 1 small piece of steel, other anomaly over 36" deep (could not dig)	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	235	523886.11	5271385.61	6.47	0.160	0.28	size=155mm	?	piece of angle iron 8" long, 3" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	239	523857.28	5271428.75	7.36	0.147	-0.04	size=155mm	?	large piece of metal, some type of frame, 1 ft BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	243	523944.60	5271385.86	6.15	0.104	0.23	105mm size	?	debris field, 3 items brought to surface	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	254	523970.80	5271298.05	8.17	0.280	0.21	large inverted target, some geology	?	1" diameter, 3' long, 3-4" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	278	523951.44	5271097.61	7.10	0.112	0.04	nice small target			?
non-Navy Propery non-AETC Selected for Dig	281	523935.30	5271043.57	9.30	0.174	0.09	size=155mm, mild remnant moment, deep water	?	drive shaft, 3" BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	285	523919.12	5270994.60	7.81	0.271	0.04	very large target, four good passes, large remnant moment	MBMT, deep water on surface, ?	small chunk of steel, 2" BBS	Recovery much smaller than Anomaly
non-Navy Propery non-AETC Selected for Dig	306	523959.99	5270626.86	7.50	0.134	0.05	medium target w remnant moment		large piece of pipe, 4-5" in diameter, unknown length, 2' BBS	Recovery Consistent with Anomaly and Analysis
non-Navy Propery non-AETC Selected for Dig	324	523931.27	5270424.56	8.32	0.115	-0.15	small target			?
Other Targets on Navy Property	N53a	523538.73	5270065.98	8.02	0.213	0.47	Small for an 8in projo, dig it		Large, deep in mud, handle on one end	Insufficient info to evaluate

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
Other Targets on Navy Property	N89	523469.04	5270040.75	3.06	0.144	-0.16	size=155mm		copper piping w/electrical wiring	Brass/Copper recovery inconsistent with mag anomaly
Other Targets on Navy Property	N97	523479.49	5270086.52	2.6	0.204	0.17	large target, dig this		~4 ft long large steel pipe or beam	Recovery Consistent with Anomaly and Analysis
Other Targets on Navy Property	N98	523455.41	5270117.51	3.06	0.101	-0.39	large		small childs bicycle	Recovery Consistent with Anomaly and Analysis
Other Targets on Navy Property	N99	523449.07	5270115.94	2.97	0.146	-0.56	size=155mm, on surface		metallic barbed wire fence post	Recovery smaller than Anomaly
Navy Property - Non-AETC Selected Dig	N133	523489.40	5270436.05	7.19	0.145	-1.06	medium target north of Pier II, dig		no find, hard pack bottom	Diver missed Anomaly
Navy Property - Non-AETC Selected Dig	N153a	523500.28	5270227.15	5.01	0.106	0.11	small target		no find	Diver missed Anomaly
Navy Property - Non-AETC Selected Dig	N17	523490.49	5270229.82	3.71	0.131	0.50	small target		no find	Diver missed Anomaly
Navy Property - Non-AETC Selected Dig	N180	523753.23	5270969.09	5.9	0.110	0.46	small target off erland pt., deep			?
Navy Property - Non-AETC Selected Dig	N181	523752.11	5270983.81	5.91	0.118	0.06	small target north of erland pt.		scrap metal, 0 "BBS	Insufficient info to evaluate
Navy Property - Non-AETC Selected Dig	N182	523747.35	5270981.72	6.14	0.131	0.11	medium target north of erland pt.		3" diameter ~2' long, possible ordnance, 2' BBS	Recovery Consistent with Anomaly and Analysis
Navy Property - Non-AETC Selected Dig	N186	523696.66	5270983.00	3.23	0.123	-0.29	small target, north or erland pt, near shore, shallow		large anomaly, not exposed due to water depth, no dive equipment was being used	Insufficient info to evaluate
Pier 1	N109	523473.16	5270239.32	4.71	0.195	-0.22	large target sout of Pier I, dig it, 1		4' x ' concrete block anchor with 8-10" eye bolt, 0" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N111	523473.71	5270265.09	5.57	0.318	0.09	very olarge target south of Pier I, 1		small entrenching tool	Recovery much smaller than Anomaly, Diver missed target
Pier 1	N113	523459.63	5270287.02	5.47	0.616	0.20	massive target south of Pier I		large piece of round steel with extensions sticking off, 0" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N122	523430.58	5270326.50	3.71	0.468	0.12	extremely large target between Piers		large piece of steel, possible wheel, 8" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N18	523497.04	5270232.14	4.67	0.084	0.06	small target shallow		no find	Diver missed Anomaly
Pier 1	N22	523511.85	5270231.71	7.28	0.254	-0.01	large target near surface		other end of N24	Not possible, N24 is 5 meters away
Pier 1	N24	523511.50	5270236.22	7.28	0.282	0.56	size=8in, south of pier 1		large piece of swteel, 2" thick, 6' long, sitting vertically in water	Recovery Consistent with Anomaly and Analysis

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
Pier 1	N28	523488.30	5270251.08	4.17	0.237	0.51	large object in pier 1 clutter field		50 cal w/powder residue and coca cola can, 3" BBS **(MEC)**	Brass and Al are inconsistent with mag sensors, diver missed target by picking up shallow clutter.
Pier 1	N33	523427.86	5270272.74	3.15	0.319	0.53	Very large target, west of pier 1, dig it		no find, deep mud	Diver missed Anomaly
Pier 1	N38	523422.66	5270292.01	4.98	0.161	-0.03	size-155mm, whallow near pier 1		large piece of steel, 5" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N39	523437.98	5270301.59	3.7	0.248	0.08	size=8in, shallow, near pier 1		no find, wood piles, no metal	Diver missed Anomaly
Pier 1	N45	523508.95	5270257.61	7.08	0.243	-0.02	size=8in, near pier1		large piece of steel block, steel pipe, 50 cal, 6" BBS **(MEC)**	Recovery Consistent with Anomaly and Analysis
Pier 1	N46	523491.26	5270268.33	4.46	0.360	-0.21	very large shallow target near pier 1		large piece of sheet metal or plate, old pier piling with rope, 0" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N47	523494.64	5270270.92	4.5	0.286	-0.05	size=8in, shallow near pier 1		2 pieces of 1" diameter pipe, 1 piece on surface 16" long, 1 buried vertical - 1-3" BBS	Recovery Consistent with Anomaly and Analysis
Pier 1	N53	523525.89	5270262.55	7.95	0.429	0.41	very large target near pier 1		big, steel rectangular shape, maybe I-beam, partially buried	Recovery Consistent with Anomaly and Analysis
Pier 1	N66	523413.97	5270303.72	4.69	0.274	0.01	large shallow target west of pier 1		no find	Diver missed Anomaly
Pier 2	N124	523445.73	5270343.63	2.55	0.456	0.18	very large target SW of Pier II		misc. scrap metal, 12" BBS	Recovery inconsistent with massive anomaly
Pier 2	N125	523458.91	5270329.48	6.36	0.170	0.11	medium target south of Pier II		concrete block with piece of cable, 0" BBS	Recovery Consistent with Anomaly and Analysis
Pier 2	N128	523504.83	5270349.98	6.16	0.536	0.61	massive target south of Pier II		1" diameter bar, 3' long, 4" BBS	Recovery inconsistent with massive anomaly
Railroad Pier	N204	523689.73	5271100.71	2.32	0.166	0.22	medium target under rr pier		5" diameter, long metal cylinder, dug down 2' BBS, pulled from bottom with boat **(MEC)**	Recovery consistent with Anomaly. X-Ray shows cartridge case (no projectile) inside container, maybe 105mm
Railroad Pier	N216	523660.34	5271107.64	3.73	0.184	-0.06	medium target north of rr pier		angle iron on surface	Recovery Consistent with Anomaly and Analysis
Railroad Pier	N222	523673.51	5271119.19	3.17	0.307	0.67	very large target north edge of rr pier		metal fence post on surface	Recovery Consistent with Anomaly and Analysis
Railroad Pier	N239	523740.07	5271143.56	8.66	0.185	0.16	large target just east of rr pier end, shallow, dig		large chunk of metal, 15" x 15" box, 8-10" BBS	Recovery Consistent with Anomaly and Analysis
Railroad Pier	N241	523756.62	5271145.19	8.24	0.131	-0.10	medium target east of end of rr pier, shallow		debris field, fishing reel, wooden box, 0-4-12" BBS	Recovery inconsistent with anomaly

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
Railroad Pier	N244	523759.28	5271159.09	8.06	0.176	0.23	medium target at east end of rr pier		debris field, broken up wooden crate, possible grenade, 0-4-12" BBS	Recovery much smaller than anomaly. X-Ray shows ornamental piece-like on top of flag pole
Railroad Pier	N247	523739.49	5271163.84	8.94	0.119	-0.08	small target east end of rr pier		debris field, cans, railroad spike, 0" BBS	Recovery Consistent with Anomaly and Analysis
Railroad Pier	N248	523725.17	5271173.17	8.85	0.191	-0.94	large target east end of rr pier, shallow		no find	?
Railroad Pier	N251	523716.83	5271188.46	8.83	0.176	-0.27	large target NE of RR pier, shallow		no find	?
Railroad Pier	N260	523708.71	5271203.51	8.04	0.251	0.11	part of large target cluster north of rr pier		1" diameter cable, length unknown, started at 0" BBS and went to 12" BBS	Recovery Consistent with Anomaly and Analysis
Railroad Pier	N264	523758.73	5271196.91	8.4	0.193	0.00	large target at end of rr pier		beer cans, 0" BBS	Recovery inconsistent with mag anomaly, diver missed target
Railroad Pier	N267	523757.52	5271209.42	8.39	0.221	-0.07	large target beyond end of rr pier		4' long rebar, 5" BBS	Recovery Consistent with Anomaly and Analysis
S. and N. of Elwood Point	N153	523688.15	5270765.12	6.69	0.208	-0.28	large target, shallow		3" diameter, 4' length of pipe	Recovery Consistent with Anomaly and Analysis
S. and N. of Elwood Point	N160	523685.09	5270830.27	3.55	0.359	-0.19	very large target in cove		large flat piece of metal, 3' x 5' , metal breaking apart while digging on item	Recovery Consistent with Anomaly and Analysis
S. and N. of Elwood Point	N164	523638.84	5270832.71	3.87	0.224	-0.12	large target near shore in cove		3" diameter, 3' length piece of pipe, 6" BBS	Recovery Consistent with Anomaly and Analysis
S. and N. of Elwood Point	N172	523692.53	5270956.64	2.33	0.114	-0.19	medium target, near shore, off erland pt.		railroad tie plate, 6" BBS	Recovery Consistent with Anomaly and Analysis
S. and N. of Elwood Point	N184	523694.19	5270974.89	3	0.260	0.53	large target near shore, north of erland pt. deep		5" diameter pie, 6-8' long, 0" BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	9	523727.37	5269961.12	6.55	0.114	0.29	good target, size of 105mm	far south area, 1 ft deep, dig	2" wide by 10 ft long, bent pipe, 6" BBS	Recovery (if steel) is much larger than the anomaly
Targets Remaining on Dig List	25	523761.35	5270021.35	6.71	0.177	0.06	target size=155m	south area, shallow, dig	20 or more pieces of metallic debris	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	36	523860.84	5270067.58	5.68	0.135	0.07	size=105/155mm	south area, shallow, dig	broken chunks of metal from circular object the size of a wheel rim, 4 " BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	147	523799.57	5270454.40	7.48	0.181	0.36	size=155mm, other targets 5m S & E	mid-bay, 1 ft deep, dig	tubing/pipe, large amount, surface and buried	Recovery Consistent with Anomaly and Analysis

Table 11. Continued

Targets Associated With?	Target ID	UTM X (m)	UTM Y (m)	Water Depth (m)	Target Size (m)	Burial Depth (m)	Analyst Comments	Analyst Comment Inserted into Dig Sheet	Diver Description of Object Discovered	McDonald Comments on Dig Results
Targets Remaining on Dig List	233	523792.72	5271329.31	7.77	0.190	0.04	size=8in	on surface, north of erland, dig	3" diameter pipeover 3' long (length unknown), 5" BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	261	523919.66	5271263.43	6.91	0.248	-0.05	excellent very larget target, others 5 m north	on surface, dig	hollow cone shaped piece of metal, 2' diameter, 18" high, 0 BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	269	523902.85	5271185.03	6.19	0.186	-0.33	perfect big target	north of Erland, dig	6" diameter pipe, 3' long, with small pieces of metal around it, 12-18" BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	276	523952.95	5271130.14	6.91	0.175	0.04	size=155mm	on surface, north of erland, dig	cover of outdoor grill on surface, 0" BBS	Recovery Consistent with Anomaly and Analysis
Targets Remaining on Dig List	361	523637.85	5270286.64	6.26	0.861	0.79	target=volkswagen, 2nd target 3m SSW, dig it	see 362	possible angle iron, 6" BBS	Recovery inconsistent with massive anomaly
Targets Remaining on Dig List	362	523633.92	5270282.12	6.07	0.397	0.28	very large target, monster target 3 m NNE, dig	should check out 361 & 362, dig	part of motor block (felt two spark plugs), 3" BBS	Is this target 361?
Treasure Box or dump site (aka oil pier)	N7	523523.70	5270083.63	5.54	0.560	8.20	12X18m rectangle filled with ~20 objects, Treasure?		rusted steel box w/lots of cable around it, 0" BBS	So what is all this stuff? And what's inside?
non-Navy Propery non-AETC Selected for Dig	248	523910.85	5271384.88				small		large chunk of oblong metal, 1 ft BBS	Recovery Consistent with Anomaly and Analysis
	N101								2" diameter pipe, 3' long 6-8" BBS	Recovery Consistent with Anomaly and Analysis
	N102								large anomaly, too deep to dig, over 10" deep	Insufficient info to evaluate

8.0 COST ASSESSMENT

8.1 The Cost Model

The cost model for this survey is based upon the site preparation, mobilization, demobilization, and survey production costs. Per instruction for the preparation for this report the breakdown of the approximate capital costs (as detailed in the Demonstration Plan) for developing and fielding the equipment are also included. The cost breakdown is shown in Table 12.

8.1.1 Capital Costs: The capital costs for the development and fielding of the equipment are approximations. They include SAIC labor costs, hydrodynamic and engineering design modeling, the equipment component costs, the component and system integration costs, the shakedown and testing costs. They do not include the project management, project reporting, support facility costs, and other incidentals such as purchase of specialized equipment to support the development, license and permit fees, etc. The approximate capital costs for the development are $1.9M. We estimate that a copy of the complete MTA system could be reproduced today for $0.8-1.0M.

As of the writing of this report the MTA system has supported 6 large scale field demonstration surveys at ordnance/ammunition depots and former ordnance training and testing ranges. The repair and maintenance costs for the MTA have averaged about $10K per survey.

8.1.2 Site Preparation Costs: Site preparation costs are usually a substantial component of the MTA demonstrations. In this case NAVFAC Northwest (in conjunction with NEODTC and the Bremerton EOD Detachment, and NAVFAC subcontractors) prepared a marine Prove-Out-Site and a marine Calibration and Test Site. The GPS base station points were also resurveyed by NAVFAC and they also provided onsite office facilities and a secure storage area for our equipment.

Because the MTA survey operations did not directly support any target investigation or recovery operations, the demonstration survey was considered as non-intrusive, which significantly reduced the requirements for development of a detailed health and safety work plan, which would include MEC operations. An explosives safety submission was not required. The HASP that was prepared addressed the typical activities for operation of a vessel in protected waters and emergency diver intervention in case of MTA sensor platform accidents. The Demonstration Plan from the first MTA demonstration (on Currituck Sound) also reduced the development work for these support documents.

8.1.3 Mobilization Costs: Mobilization costs are based upon preparation and shipping of all MTA support equipment from Cary, NC to the Puget Sound demonstration site. Shipping was by means of dedicated trailer motor freight. This mobilization was unique in that it had to take place as a three step operation. Equipment was motor freighted to Shilshole Marina in downtown Seattle where it was unloaded by a marina operator using heavy equipment.

Table 12. Cost Breakdown Structure for the Ostrich Bay Demonstration

Cost Element	Data Tracked During Demonstration	Estimated Cost ($K)
Capital Costs Instrumentation	Capital Equipment Purchase	600.0
	Ancillary Equipment Purchase	200.0
	Equipment Development, In-House	300.0
	Equipment Integration/Shakedown	400.0
	Software Development	200.0
Site Preparation	Evaluation Trip	4.0
	Establish First-Order GPS Points	0.0
	Establish Prove-Out-Site	0.0
	Establish Moorings on Site	3.0
	Develop HASP	5.0
	Develop/Approve Demonstration Plan	10.0
Mobilization Costs	Airfare	4.0
	Equipment Prep and Loading	2.8
	Equipment Transport (Cary to Seattle)	8.4
	Equipment Unloading & Transport to Silverdale	7.0
	Equipment Setup/Ferry to Ostrich Bay	7.0
Survey Operation	**Item Costs**	
	Rental Vehicles	3.7
	Chase Boat Rental	2.5
	Diver Support	26.0
	Equipment Spares Used	6.0
	Misc Logistics Costs	3.0
	Daily Costs	
	Daily Labor Support Costs (4 Men with per diem)	6.9
	Daily Diver Costs (Boat Gas, Hardware)	2.5
	Incidental Costs	1.6
	Total Survey Cost (19-27 June)	98.6
	Survey Cost/Hectare	8.5
	Cost/Survey Hour	6.6
	Number of Survey Personnel	5 (With Diver)
Demobilization Costs	Equipment Recovery, Prep, Loading	11.0
	Equipment Transport (Seattle to Cary)	6.8
	Equipment Unloading/Transport to Depot	5.5
	Equipment Repair, Component Replacement	10.0
Survey Products	Data Processing	11.8
	Onsite Meeting Support	3.0
	Target Analysis	3.0
	Survey Graphics Products	4.0
	Target Investigation, Diver Support Products	3.0
	Diver Performance Analysis	4.0
	Survey Report	25.0

The MTA tow vessel was transported by water (20 miles from Seattle to the Silverdale Marina); and the remainder of the equipment was transported by box truck (sensor platform on a boat trailer) to Silverdale (50 miles). The MTA sensor platform and tow vessel were assembled, mated, launched, and tested at this marina and then were ferried about 6 miles to the prepared moorings adjacent to Pier II in Ostrich Bay where the equipment remained until survey operations were completed. The chase boat was used morning and night to transport the crew to another marina where we had access to our vehicles.

8.1.4 The Survey: The survey operation costs are broken out several different ways in Table 11, as required by the instructions. The active surveying took place over a period of 9 days, which included one rest day. Per diem costs were included for the rest day, but other costs were prorated over the 8 actual survey days. Four SAIC persons and one contract diver supported the survey. The diver was associated with the chase boat, except when he was supporting repair or recovery operations. One person was always on shore in the on-site office facility. He was responsible for processing raw survey data, conducting QC evaluations, and running errands, as required, to support the survey vessel. The MTA vessel was operated with either 2 or 3 persons. When 3 persons were on board, two of them took turns operating the vessel, which is tedious, particularly when working in tight areas on windy days with significant surface chop. The 3rd person, when not driving was typically involved in oversight, planning operations, monitoring deck conditions and gas levels, etc. About one-half of the time the third person (from the MTA vessel) worked on shore in the office carrying out target analyses, preparing presentation materials and graphics for progress reports to NAVFAC and EPA representatives or meeting with other stakeholders or visitors.

8.1.5 Demobilization: These operations took place as the inverse of the Mobilization process. The MTA system was ferried to Silverdale where it was recovered, dismantled, loaded onto the boat trailer and into the box truck and transported to Shilshole Marina in Seattle. The MTA tow vessel was driven through Puget Sound to Shilshole and recovered onto the boat trailer. All equipment was loaded onto a dedicated 45 ft flatbed trailer and returned to Cary, NC where it was dismantled, repaired, and stored for the next operation.

8.1.6 The Survey Products: The cost of the various survey products are detailed in Table 12. The products themselves are described in the text of this report.

8.2 Cost Drivers

The primary cost drivers for MTA surveys are the labor costs associated with the survey, the mobilization/demobilization costs, and the site preparation costs. In this demonstration, the site preparation costs and facility support costs were borne entirely by NAVFAC. The mobilization costs were substantial for this demonstration because of the complex multi-step deployment requirements. In fact, in all 6 of the MTA demonstrations, there have been no adequate launch/recovery facilities or docking facilities accessible to or near the work site. Our best partial remedy, which we learned in both the Currituck Sound and the Puget Sound demonstrations is that it is most convenient, efficient, and least expensive to moor the complete MTA system on the work site during the entire operation. In some cases this has required us to station security personnel on the vessel overnight; but this is much less expensive and time consuming that long morning and night ferry trips with the deployed system.

It is our experience that the MTA system must always be deployed with a chase boat and a UXO-certified diver. In many cases MTA operations take place many miles from a dock (or even the shore) and we have found that many repairs can be done in the water by the diver. We have also concluded that it would be unwise to undertake a survey operation with less than the 5 person crew that supported this operation. For a very short operation a survey could be conducted by two persons manning the MTA vessel and one person in the chase boat. However, any operation longer than one day really requires someone on shore to monitor and process the data and a fifth person to think, plan, and provide relief to the vessel driver.

A performance improvement and potential cost efficiency could be realized if the sensor platform was redesigned to reduce weight by 50-60% and to allow it to fold or collapse so that it could be efficiently hoisted onto the deck of the tow vessel. The current system has proven to be impractical to launch from and recover to the deck. If the sensor platform were easily and quickly recoverable, it would allow fast transport (15 kt rather than 2 kt) to and from the worksite. Additionally, in almost all cases the marinas or docks that we have tried to work from have channel width and/or channel depth limitations that make it almost impossible to dock the fully deployed system. Tides or water levels often limit access to certain times of the day or to a limited set of weather conditions.

8.3 Cost Benefit

It is difficult to evaluate the cost benefit of the MTA in comparison with other marine UXO survey approaches because there are no other comparable platforms available with which to compare. The MTA could be compared with other UXO survey technologies that provide similar quality survey products, e.g. 3-dimensional mapped data files that will support detailed target analyses, creation of survey graphics and GIS documents, and subsequent target relocation, investigation, and recovery operations.

The information provided in Table 12 for this demonstration show that the MTA survey operations are less expensive than operating man-portable carts on land surveys (on a per hectare basis) and are similar in cost to operating (MTADS type) vehicular towed arrays on land. The helicopter magnetometer arrays are, of course much less expensive on a cost per hectare basis. The MTA detection sensitivity is significantly better than the helicopter array, approaching that of the vehicular arrays. In addition, it should be pointed out that the MTA is still a pre-prototype demonstration platform and the other system costs are based upon commercial platforms.

9.0 IMPLEMENTATION ISSUES

9.1 Environmental Checklist

The environmental issues associated with this demonstration took place within the ongoing RI/FS being conducted under CERCLA guidelines by NAVFAC Northwest. All operations were coordinated with and monitored by EPA Region 10 representatives. The MTA operations associated with this demonstration survey were non-intrusive and did not require permits, explosives safety submissions, and were not subject to local environmental constraints.

9.2 Other Regulatory Issues

All of our activities were coordinated with NAVFAC Northwest and were conducted within the constraints of the NAVFAC operation plan and the ESTCP Demonstration Plan. Both plans were reviewed and approved by the Washington State Department of Natural Resources, the Suquamish Tribe, and EPA Region 10. All requests for information, site visits, and presentations to site visitors during the MTA operations were overseen and coordinated with Mr. Mark Murphy of NAVFAC Northwest.

9.3 End User Issues

The most likely end users of this technology are the commercial UXO service provider firms, in association with ACE/Huntsville and the Regional Offices of the Corps and individual DoD installation commanders. Other likely users include the various divisions of NAVFAC and Navy/Marine Corps installation managers who are responsible for training ranges with marine UXO contamination problems. The results of this demonstration are being monitored by members of the Army Corps, NAVFAC, and the Navy NOSSA office, and ERDC.

The instrumentation used in this demonstration is a custom-built prototype. However, with a few exceptions, it has been constructed with COTS components. The unique components in the Marine Towed Array are the fiberglass sensor platform, the tow cable and underwater electronics housings, the EM68 sensor, the pilot guidance display and software, and some custom-designed printed circuit boards. Each of these components is fully documented and described in various reports, and could be purchased from the original manufacturers. There are no proprietary technologies embedded in the Marine Towed Array.

9.4 Availability of the Technology

The complete MTA system remains the property of ESTCP. It is housed and maintained by SAIC at our facilities in Cary, NC. It is operational and available to support other demonstration surveys sanctioned by ESTCP.

SAIC independently owns a limited amount of MTA-related equipment and could independently support certain types of limited marine UXO survey operations. SAIC is interested in and would support the creation of a fully-capable MTA platform if an end user were identified that could provide enough work to justify the investment costs of fielding a fully capable privately-owned system.

10.0 References

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4. "Biological Evaluation of the Jackson Park Navy Housing Area – Ostrich Bay Geophysical Test Site," John A. Miller, NAVFAC Engineering Command Northwest, February 2006

5. UX-1322 SERDP Project, http://www.serdp.org/research/UXO.html

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14. “Sidescan Sonar Survey Data Report, OU-3M, Jackson Park Housing Complex/Naval Hospital Bremerton, Bremerton, WA,” Naval Facilities Engineering Command, Engineering Field Activity, Northwest, November 15, 2004

15. “Work Plan for Marine Geophysical Prove Out Installation at OU-3M, Jackson Park Housing Complex, Ostrich Bay,” Naval Explosive Ordnance Disposal Technology Division, January 2006

APPENDIX A – Points of Contact

Organization	Point of Contact	Role in Project	Phone/Fax/Email
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APENDIX A – Points of Contact, Continued

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Seaview West Boat Yard 6701 Seaview Ave NW Seattle, WA 98117	Christina	Strap Lift and Fork Lifts for Truck Loading	Tel: 206-783-6550
Shilshoal Marina Seattle, WA 98117	Gloria Jones	Ramp to Launch Pontoon Boat	Tel: 206-728-3368 Tel: 800-426-7817
Golden Gardens Park 8498 Seaview Place Seattle, WA		Public Boat Launch	Tel: 206-684-4075
Silverdale Marina Silverdale, WA		Ramp to Launch Sensor Platform	
Overnight Trucking Raleigh, NC	Joey Mills	Lift Pontoon Boat onto Flatbed Trailer	919-232-2200
Meridian IQ Trucking Company	Bob	Transport Equip. to Seattle, WA	913-906-6742
Flagship Inn 4320 Kitsap Way Bremerton, WA 98312	HOTEL		Tel: 360-479-6566 800-447-9396