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Travelogue and Phenomenology Report

UXO Detection and Characterization in the Marine Environment

ESTCP Project MM-0324

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SAIC

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14. ABSTRACT
(UU) Beginning in 2003 SAIC (formerly AETC) developed the Marine Towed Array for underwater geophysical investigations. The underwater towed platform is a 5 m wide array containing 8 Cs vapor magnetomers. It is towed by a 60 ft cable by a pontoon boat. The attitude and depth of the sensor platformis controlled by an autopilot. The inputs to the autopilot include a tactical grade IMU, depth sensors and digital magnetic compasses, and a dual GPS systme based upon the tow vessel. The survey products include digitally geo-referenced magnetic anomaly maps of metallic objects buried in the sediment and spreadsheet tables reporting the results of analyses of individual anomalies. The system has been used to conduct six extensive underwater surveys. In this report we discuss the actual site conditions, how they affected the system operation, and how the system was adapted during the demonstrations in response to new environmental challenges that were encountered.

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UXO, underwater geophysics, ordnance detection and classification, marine magnetometers

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ACRONYMS

Acronym	Explaination	Acronym	Explaination
ASR	Archives Search Report	LCM	Landing Craft Marine
AFTWA	Atlantic Fleet Weapons Training Facility	LIA	Live Impact Area
ARL	Army Research Laboratory	MEC	Munitions and Explosives of Concern
BRAC	Base Realignment and Closure	MLLW	Mean Lower Low Water
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act	MMRP	Military Munitions Response Program
DEM	Digital Elevation Model	MRP	Munitions Response Program
DERP	Defense Environmental Restoration Program	MTA	Marine Towed Array
DNER	Department of Natural and Environmental Resources (Puerto Rico)	MTADS	Multi-sensor Towed Array Detection System
DoD	Department of Defense	NASD	Naval Ammunition Support Detachment
DOI	Department of Interior	NOAA	National Oceanographic and Atmospheric Administration
DOQ	Digital Ortho Quad	nT	nanotesla
DMM	Discarded Military Munitions	NAD	North American Datum
EE/CA	Engineering Evaluation/Cost Analysis	NATO	North Atlantic Treaty Organization
EFA	Environmental Field Activity	NAVFAC	Naval Facilities Command
EMI	Electromagnetic Induction	NEODTD	Naval Explosives Ordnance Detection Technology Division
EOD	Explosive Ordnance Disposal	NOSSA	Naval Ordnance Safety and Security Activity
EOTI	Explosive Ordnance Technology Inc.	NPL	National Priorities List
EMA	Eastern Maneuver Area	NSWC	Naval Surface Warfare Center
EMI	Electromagnetic Induction	OEW	Ordnance and Explosive Waste
EPA	Environmental Protection Agency	OU3M	Operational Unit 3 Marine
ESTCP	Environmental Security Technology Certification Program	PNNL	Pacific Northwest National Laboratory
FRF	Field Research Facility	Projo	Projectile
ft	Foot	RDT&E	Research and Development, Test and Evaluation
FUDS	Formerly Used Defense Site	SAIC	Science Applications International Corp.
GIS	Geographic Information System	SERDP	Strategic Environmental Research and Development Program
GP	General Purpose	SI	Site Investigation
GPS	Global Positioning System	SIA	Surface Impact Area
ha	Hectare	SUV	Sports Utility Vehicle
Hz	Hertz	TCRA	Time-Critical Removal Action
IMU	Inertial Measurement Unit	USACE	US Army Corps of Engineers
JPHC/NHB	Jackson Park Housing Complex, Naval Hospital Bremerton	UXO	Unexploded Ordnance
Knot	Nautical Mile per Hour = kt	VNTR	Vieques Naval Training Range
km	Kilometer	WAA	Wide Area Assessment
lb	pound	WWI	World War One

1.0 Introduction – Ordnance Contamination in the Marine Environment

The investigation of, characterization of, and the recovery/disposal of munitions contamination on U.S. ranges, training areas, and lands adjacent to these areas has been a subject of study (and to a more limited extent) cleanup activities for many decades. Much of this activity has been associated with former ranges (and former defense sites), which have previously been returned to the civilian sector with residual munitions contamination. The amount of land area associated with possible munitions contamination has been variously estimated from as little as "a few" million acres to as much as 10-20 million acres. The definition of Formerly Used Defense Sites (FUDS) is limited to those sites that were formerly transferred from DoD control before October 1986. There are more than 9,000 identified FUDS properties. A subset of the FUDS properties on which Munitions and Explosives of Concern (MEC) are known to pose a hazard to human safety, fall within the Military Munitions Response Program (MMRP).[1] There are more than 1,600 MMRP sites currently within the FUDS inventory of 9,000 sites. Munitions responses on all the FUDS are the responsibility of the Army Corps of Engineers. The annual budget of the Corps for managing the FUDS is ~$250M.

Of the 1,600 MMRP sites, at least 442 sites are known or suspected of having MEC in underwater areas. This information is preliminary, and the number may grow as more of the MMRP sites are investigated. Figure 1-1 shows a pictorial of the distribution of the MMRP sites that have identified as underwater MEC contamination. These sites (identified in green for inland water ranges and in blue for tidal range , stretch from the far western Aleutian Islands, south to include several of the Hawaiian Islands, and eastward to include the US mainland and territorial areas of Puerto Rico and other offshore areas. This map was provided by the ESTCP Program Office from the Army Corps of Engineers database Mr. Andrew Schwartz in a 2007 presentation at an ESTCP Underwater Workshop,[2] estimated that the water area involved in underwater MMRP sites is in excess of 10 million acres. As noted above, the FUDS properties include only military properties transferred to civilian control before October 1986.

The Navy also has a Munitions Response Program (MRP) that deals with marine sites separately from the Army Corps MMRP. The Navy MRP sites include only areas where Navy actions are identified as responsible for the MEC releases. Only shallow water areas (<120 ft deep) where releases took place before 2002 are included. Areas that lie between high and low tide are excluded, as are disposal sites, FUDS properties, former combat areas, and areas associated with (terrestrial or water) operational ranges. Current responsibility for the MRP sites is associated with the various NAVFAC Engineering Commands. Mr. Bryan Harre, also at the 2007 ESTCP Underwater Workshop, identified 13 MRP sites associated with the regional Engineering Commands and an additional 10 Navy MEC sites that predated the formation of the Navy MRP.[3]

In addition to the Army FUDS/MMRP and Navy MRP sites many other sites with significant underwater MEC contamination exist that do not fall within the restrictive definitions of the MMRP and MRP lists. These include sites associated with active (or formerly active) ranges and military installations where extensive training takes place that have not been transferred to civilian control or which fall outside the time definitions of the FUDS or MRP sites.

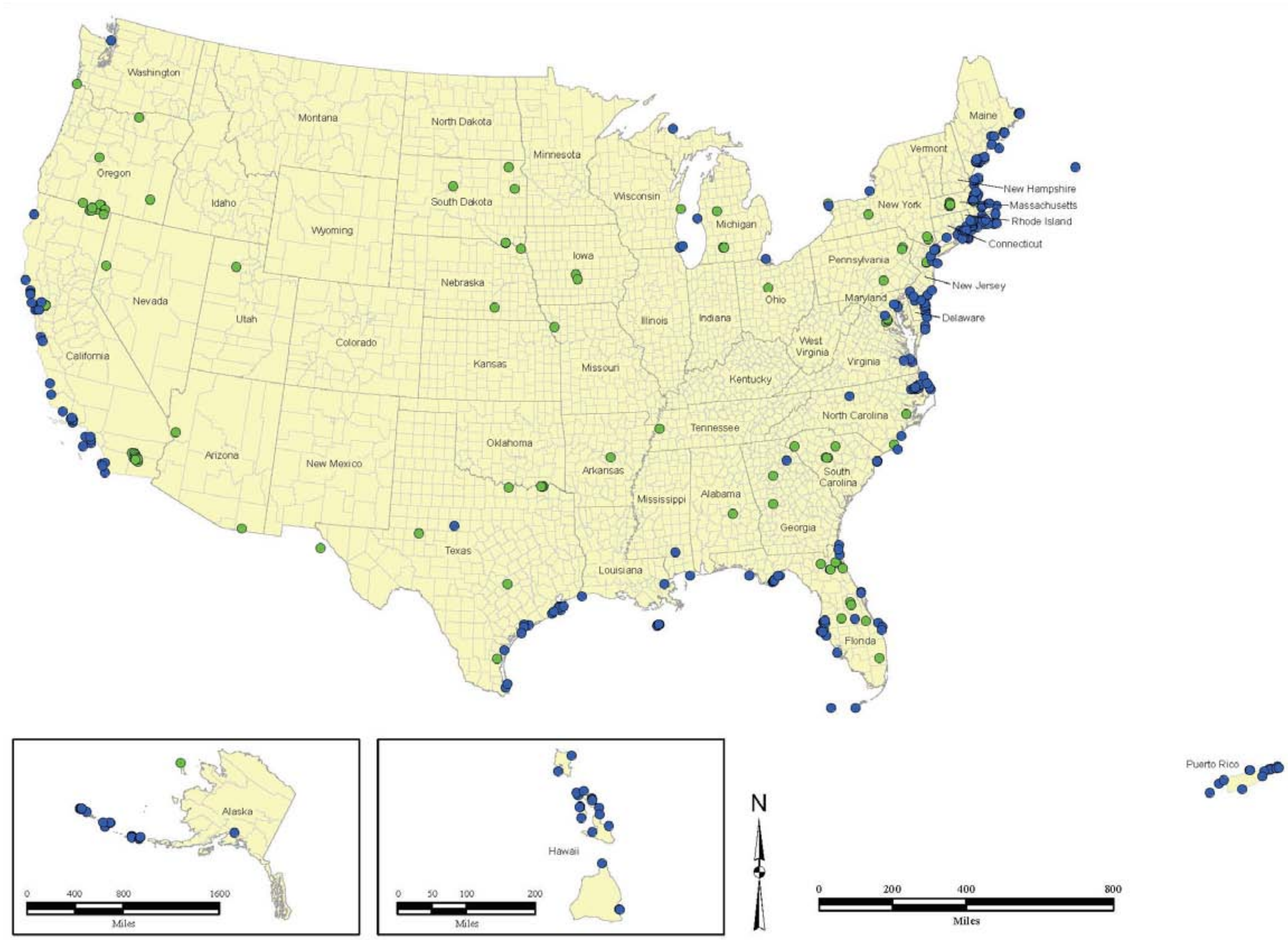

Figure 1-1. This map identifies MMRP ranges involving inland waters (in green) and those involving tidal waters (in blue).

The additional sites also include areas associated with ammunition depots, manufacturing assembly and testing of munitions, ordnance shipping and transfer sites. There are no comprehensive lists of these types of sites that I am aware of, but it is very easy to identify many of them. Within a short driving distance from our Cary, NC offices, sites with extensive underwater MEC contamination include:

- Many square miles of training and impact ranges associated with the Camp Lejeune Marine Base and the Cherry Point Naval Air Station. These include extensive areas of the near shore Atlantic, thousands of acres of marine estuaries, bays, tidal wetlands, and rivers, lakes and ponds;
- Tens of thousands of acres of the Dare County Bombing Range with MEC contamination in marine areas, in swamps and wetlands, and in rivers and bays. This range is used by several Naval and Air Force installations for airborne training.

Within a short driving distance of Washington, DC similar vast areas with known MEC contamination exist that do not fall within the FUDS/MMRP or Navy MRP categories. These include:

- Several ranges and impact areas within the Chesapeake Bay (encompassing tens of thousands of acres, or perhaps more) are currently or formerly used as training targets by the Patuxent River Naval Air Station and other Navy and Air Force installations as far south as the Norfolk area and as far north as Delaware.
- The Army Research Lab (Blossom Point) and the NSWC (Dahlgren) across the Potomac River from each other have used more than 20 miles of the Potomac River as an impact range for mortars, rockets, and bombs (Army) and for small and large projectiles (NSWC) for decades. The total area of these active and recently active ranges likely encompasses more than 100,000 acres and extends more than 20 miles down the Potomac River from these facilities.

The recitation of these examples is meant to be illustrative, not inclusive. In general, the areas of underwater MEC contamination are neither isolated nor geographically concentrated. They involve the full range of fresh and salt water sites from small ponds and rivers, to the Great Lakes, vast areas of swamps, wetlands, estuaries, bays and sounds and extensive areas of the Atlantic, Pacific, the Gulf of Mexico, and the Caribbean. The total amount of area involving underwater MEC contamination may rival the total land areas known to contain MEC residues.

The underwater MEC problem has not garnered either the attention or notoriety that UXO on land areas has, probably because it has remained largely out of sight. Increasingly however, it is not just commercial fishermen who come in contact with underwater MEC contamination. The American population is increasingly involved in water sports, recreational fishing and diving, boating and other water activities. Over the past 20-30 years vast areas of land along rivers, bays, sounds and the ocean have been developed both as resorts and for personal housing. These activities have claimed large land areas formerly associated with (and adjacent to) military ranges. Additionally, there have been some high visibility examples of marine MEC contamination (Hawaiian and Caribbean Islands) where attempts have been made to return military training areas to civilian control without clearing them of MEC contamination.

Underwater MEC contamination is a subject of increasing visibility and will require development of new tools and techniques.

The geophysical exploration tools that have been developed and refined for investigating MEC contamination on land are not appropriate for or adaptable for use in underwater geophysical site characterizations. The large corps of UXO and EOD workers trained and certified by the DoD for military clearance operations on active ranges have been and are readily available for similar commercial investigations and clearances. The tools and techniques used on land by these workers are completely inappropriate for use in dealing with UXO underwater. Currently, underwater UXO searches are typically conducted by divers using hand-held metal detectors. Discovered targets are either prosecuted as they are found or they are marked with weights and floats for later reacquisition. The cost of underwater UXO site investigations and ordnance clearances have generally been considered as prohibitively expensive except in circumstances where discovered items are deemed to be an imminent threat to the public.

2.0 Development of the SAIC Marine Towed Array (MTA)

SERDP in 2002 and ESTCP in 2003, issued calls for development and demonstration of Marine UXO survey systems for application in shallow water environments (up to 15 ft water depths) associated with current and former military ranges. In our 2002-2003 SERDP Project, UX-1322, we carried out a marine engineering study of vessel parameters and sensor platform concepts and established designs for towed sensor platforms of 2 m, 4 m, and 10 m in width. We additionally carried out EMI modeling studies and parametric measurement studies with inert ordnance and established a working design for a time-domain EMI transmitter-receiver system that we predicted could be used to detect a 60 mm mortar from a stand-off distance of 1 m. Moreover, we concluded that both magnetometers and an EMI sensor array could be housed in the same sensor platform. Although they could not be operated simultaneously, each could be independently used without interference from the other system. Results of these studies are documented in the Project Final Report.[4]

In our 2003 ESTCP Project MM2003-24, we designed and constructed the marine towed-array UXO sensor system.[5] This platform, with nominally 4-meter wide sensor arrays, is designed as an underwater flying wing. It is towed by a 20-meter cable attached to a 30-foot long triple pontoon boat. The maximum design operational speed is 5 kt. Assuming the system is used to survey 4 m wide lanes at 5 kt, the survey production rate is 3.7+ hectares/hour, or slightly less than 10 acres/hour. This does not count the time spent in turns or in raising or lowering the platform. The attitude and depth of the sensor platform is controlled by an autopilot operating from a computer on the tow vessel. 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 sediment surface, or to maintain a fixed depth below the water surface. This system has provided a previously unrealized capability for underwater UXO search systems. The survey products include digitally geo-referenced magnetic anomaly maps of metallic objects buried in the bottom sediments and Excel® tables reporting the results of analyses of individual anomalies. The full array of dipole-based target analysis capabilities developed for the MTADS ground and airborne survey systems were adapted for this application.

3.0 Demonstrations and Evaluations with the MTA at Former Marine Ranges

The MTA system was first demonstrated in a large UXO marine survey in the Currituck Sound adjacent to the Former Duck Bombing Range near Duck, NC[6] in late 2005. The second demonstration of the MTA system under ESTCP Project MM2003-24 took place in Ostrich Bay (Puget Sound, WA) adjacent to the Former Naval Ammunition Depot Puget Sound.[7]

Subsequent to completing these project-specified survey demonstrations, ESTCP and the Army Corps of Engineers (Huntsville) have sponsored several additional system demonstrations at increasingly challenging sites. In part, these demonstrations have been intended to explore (and expand) the operating conditions of the MTA system to address a larger fraction of the challenges presented by the widely-varied list of underwater MEC contaminated sites.

In an attempt to bound the actual extent of the MEC contamination problem, the Defense Science Board issued a series of recommendations including a campaign to delineate areas where munitions are and where they are not.[8] To address this need, ESTCP initiated a congressionally mandated Wide Area Assessment (WAA) Pilot Program. Many of the former ranges (FUDS) are on vast western sites occupying tens of thousands of acres.[9] While all of these sites are known to have UXO contamination, it is thought that the majority of the area of each site was likely ordnance free. An approach, using combinations of sampling (transect) and comprehensive (blanket coverage) surveys successfully validated that the premise was primarily correct. These Wide Area Assessment Demonstrations validated this approach to WAA of large sites and has effectively removed many acres of inventory as areas of concern for UXO contamination.

One of the WAA sites was a water site. In fiscal year 2006, ESTCP was directed by Congress to conduct a demonstration to characterize UXO contamination impacting the Toussaint River area along the southern shore of Lake Erie in Ohio. This was the site of the Former Erie Army Depot where for 50 years most of the large gun barrels and projectiles bought by the Army were proof tested. Fifteen fixed gun emplacements (lined up in a row adjacent to each other) near the shore of Lake Erie pointing north into the Lake, were used for firing and proof testing purchased projectiles and gun barrels. The range fans for the larger guns extended almost 20 miles out into the lake, nearly to the Canadian border. ESTCP supported both airborne magnetometry surveys of the beach and near-shore areas and extensive MTA transect surveys of 50,000 acres of the Lake (extending offshore more than 16 miles). The results of these studies (and the subsequent extensive target recovery program) are described in detailed reports and on the ESTCP Website.[10-13]

UXO cleanup activities have been ongoing for several years on the eastern half of Vieques Island (Puerto Rico). This island was used for almost 5 decades for naval, land, and airborne training by the US and NATO forces. Management of the ordnance cleanup activities has remained the responsibility of the US Navy and is being managed by NAVFAC Lant. The most intense activity on Vieques took place in a relatively limited area at the eastern end of the island, referred to as the Live Impact Area. The LIA activities encompassed both land target ranges and water impact areas in three beautiful bays on the north and south shores of the island. In 2006, NAVFAC Lant hosted studies of these bays (and other shore areas) supported by

NOAA and ESTCP. NOAA conducted sonar and laser bathymetric mapping of the bays and near shore areas and NAVFAC Lant and ESTCP supported an MTA survey of the Bahia Salinas del Sur on the southern coast. The details of these activities are described in after action reports by NOAA and by SAIC.[14, 15]

As part of the same MTA field study, the Army Corps of Engineers (Huntsville) sponsored an MTA study of selected areas associated with the island of Culebra. Though less extensive than on Vieques, military operations on parts of Culebra are suspected to have left MEC contamination. Culebra is only about 12 miles from Vieques, so the MTA equipment was moved from Vieques to Culebra following the Vieques demonstration. MTA surveys of several bays along the southern shore of Culebra and around the small adjacent island of Louis de Peña were conducted. Some of the studies involved transect sampling. In three bays more extensive blanket surveys were also conducted. The details of these activities are described in a report of the demonstration.[16]

The Blossom Point Field Site, of the Army Research Laboratory's Adelphi Facility has long been a support center for development and testing of new fuzes for rockets, mortars, and projectiles. There are extensive ranges for testing these developments. Fourteen of the formerly-used ranges extended into the Potomac River and the Nanjemoy Creek. Currently, an EE/CA study is being conducted under the Army MRP. As part of this study, the MTA was used to characterize the types and levels of munitions contamination on the more than 5,000 acres of offshore ranges associated with this facility.[17]

The published reports of the six MTA demonstration surveys provide extensive detail on the historical use of the sites during the period that they were active and the types and delivery methods of ordnance dispensed at the sites. During the MTA survey operations, the demonstration reports focus on the mechanical details of the survey operations, the methods used for data acquisition and analysis, and the creation of the survey data products to support target reacquisitions and recoveries. In the demonstration reports, the discussions of the actual site conditions tend to be limited to the weather, the sea state and water surface conditions, and the difficulties of the morning and evening commutes to the worksite and how these conditions affected the actual MTA survey operations.

Considered as a group, the 6 demonstration sites are characterized by a widely varied geography, geology, topology, local ecology, accessibility, the presence of man-made hazards and obstructions, and cultural and logistics challenges. The first MTA demonstration site (Currituck Sound) conformed almost entirely to the design features and specifications implemented into the construction of the MTA system. Each subsequent demonstration added additional performance requirements, which exceeded the original system design specifications. These included the necessity of using unimproved launch sites, operating in water deeper than the system design specifications, operation in increasingly heavy seas and farther from shore, operation in open ocean waters, operation with very long logistics supply chains, requirements to use charter vessels, dodging uncharted spoil banks, navigation hazards, ship wrecks and fishing vessels. We have described in the demonstration reports the details of how the MTA was modified and adapted to accommodate these challenges. We will not repeat the discussions of the modifications of the MTA system to accommodate these challenges, but refer the reader to the original reports of the Demonstration surveys). These reports are (or soon will be) available on the ESTCP Website.

In this report we concentrate our discussions on the specific characteristics of the various survey sites. Discussions begin with a brief enumeration of the types of area uses that led the site to be considered as MEC- or DMM-contaminated and the types of operations responsible for the ordnance contamination. The areas of the survey sites, because of their differing uses vary in size by more than a factor of 200. These considerations are enumerated below in bullet form.

Types of area use

- Water Ranges; targets or impact areas in marine areas
- Land Ranges; undershoots/overshoots leading to unintended marine ordnance contamination
- Ammunition Depots; DMM contamination, primarily associated with ordnance transfer operations

Types of ordnance contamination events

- DMM; ordnance discarded or unintentionally lost during transfer operations
- Airborne Launches; aerial gunnery, rockets, bombs
- Land-fired weapons; mortars, projectiles, rockets
- Naval Platform Launches; rockets, projectiles

Area of contamination

- Up to a few hundred acres; Currituck Sound, Ostrich Bay, Bahia Salinas del Sur (Vieques)
- Hundreds to thousands of acres; Lake Erie (~100,000 acres), Blossom Point, Potomac River Combined ARL and NSWC/Dahlgren (~100,000 acres), Various Bays around Culebra and Louis Pena Island (a few thousand acres)

The demonstration survey sites have varied widely in geographical, geological, topological, and vegetative characteristics as enumerated below in bullet form.

Water Depths

- Beaches/Surf Zone up to ~50 ft. Except for the Potomac River, most areas of concern have depths of <40 ft.

Bottom Sediments

- Soft sand, soft muck, sand bars, etc; Lake Erie, Currituck Sound, Vieques, Potomac River.
- Hard sand, gravel, silt clays; Currituck Sound, Lake Erie, Ostrich Bay
- Rocky Outcrops, boulders, rocky or coral reefs; Vieques, Culebra, Lake Erie, Ostrich Bay
- Magnetically active volcanic outcropping or bottom surfaces; Ostrich Bay, Culebra

Vegetation

- Sea grasses; Extensive in Vieques and Culebra, Sparse in the Potomac River

- Little or none; Currituck Sound, Ostrich Bay, and Lake Erie

Bottom Slopes

- Benign (less than 5^o) All areas except Potomac River, and shorelines of Ostrich Bay, Vieques and Culebra
- Severe (up to or > 20^o) Dredge spoils on Potomac River

Both natural impediments and man-made uncharted hazards and obstructions characterize many of the MTA survey sites as enumerated below.

Impediments, hazards, obstructions

- Crab traps (Potomac River, Currituck Sound)
- Rocky “reefs” (Lake Erie)
- Boulders (Ostrich Bay, Lake Erie)
- Submerged posts, pilings and submerged structures; Ostrich Bay, Lake Erie (fish weirs), Potomac River
- Shipwrecks; Vieques, Culebra, and the Potomac River

In the remainder of this report we serially discuss the MTA projects, emphasizing the issues and conditions enumerated above in the bullet presentations. In some cases, top level displays of the MTA data are presented, when they are used to illustrate background interference levels or when they were used to support target investigations or recovery operations. If the reader is interested in the details of the survey findings or the results of the data analyses, they are referred to the original MTA demonstration reports, all of which are referenced herein.

4.0 The Former Duck Naval Target Facility

4.1 Range History

The Duck Naval Target Facility occupied only about 175 acres of the Outer Banks about 1 mile north of the current town of Duck, NC. The MTA demonstration survey report is provided in reference 6. The Duck range included the entire barrier island between the Atlantic Ocean on the east and the Currituck Sound on the west, stretching for about 3,000 feet north to south. While the range was active during the period of 1941 to 1965, aircraft primarily from the Norfolk Navy Yard flew to the Duck Target to conduct bombing and rocket launch practice runs.[18] Figure 4-1 shows a 1961 aerial photograph (USGS) of the range. The impact target was defined by an X-shaped group of posts or platforms that are visible in the photograph. The target was located just east of the barrier dune, which was located above the high tide mark. During most of the time that the range was active, this section of the barrier island was a very primitive area with no improved roads for access and with very little traffic except for fishermen. Access was typically accomplished by vehicles driving on the packed sand strip adjacent to the beach.

The reported flight path for the aerial bombardment approaches was from the mainland flying eastward toward the target and continuing the flight path out over the ocean. Figure 4-2 shows a more modern map. The entire target range was transferred in 1973 to the Department of the Army (Civil Works) by the General Services Administration. The Army Corps of Engineers established the FRF on the former target range to conduct marine and marine wetlands research. They built a 600-foot pier on concrete pilings extending into the ocean to a water depth of 20 feet. The FRF is currently under the direction of the Army ERDC in Vicksburg, MS. During the period since the transfer of the property in 1973, several additional UXO-related actions have occurred carried out under the direction of the Army Corps of Engineers.

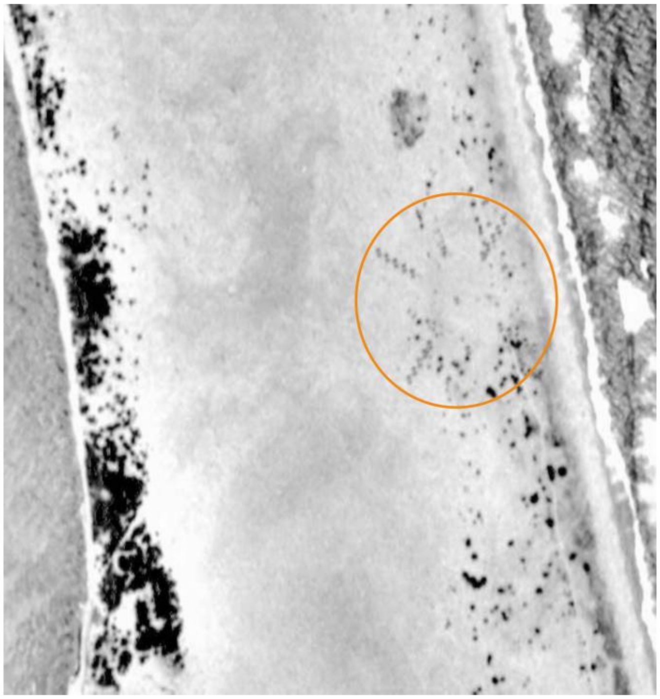

Figure 4-1. Portion of a 1961 aerial photo showing structures likely associated with the bull's eye for the Duck Target Range. The orange circle is super-imposed to highlight these structures.

Figure 4-2 is adapted from the 1996 EE/CA study carried out and reported by Parsons Engineering Science, Inc.[19] The installation of North Carolina State Route 12 (a two lane asphalt road) allowed the northern part of the island to be developed. Currently, the barrier island is almost entirely occupied by resort beach homes (as shown in the Figure immediately north and south of the former range property boundaries).

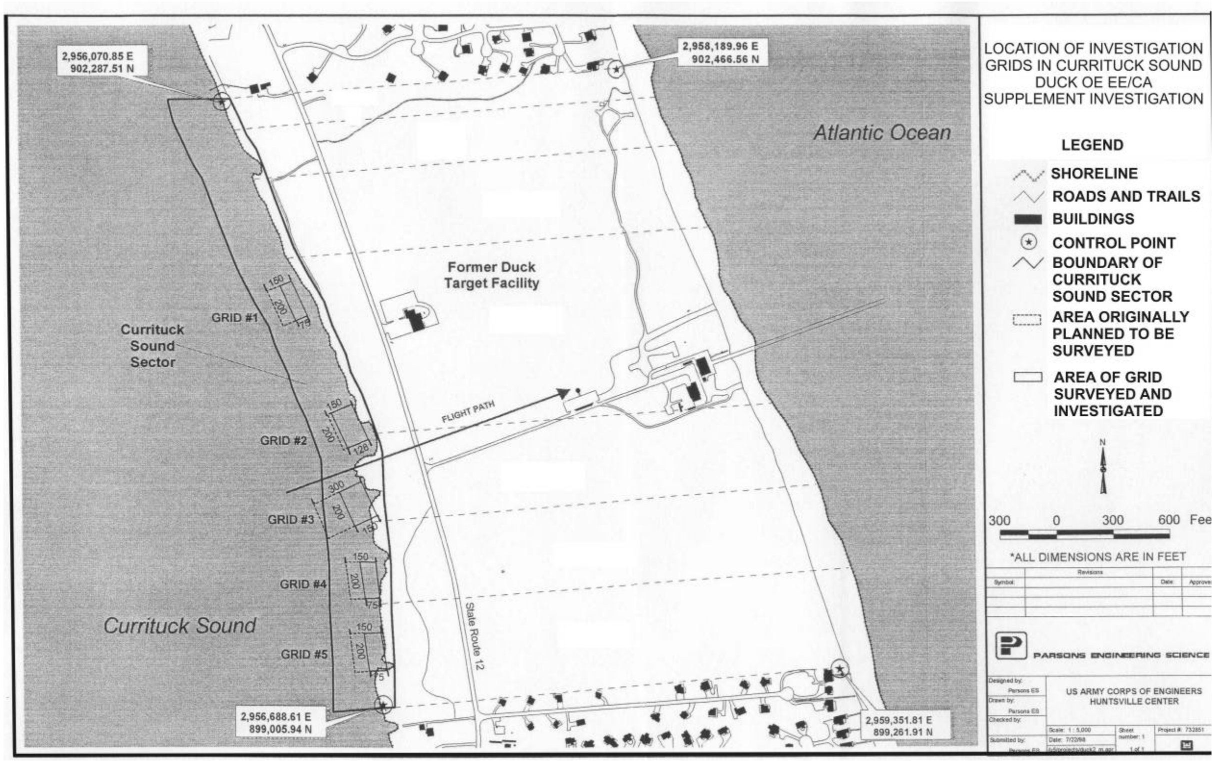

Figure 4-2. Map of the Former Duck Target Range showing current roads and structures associated with the FRF and the Duck Volunteer Fire Department. Also shown is the presumed flight path used by naval aircraft on bombing and aerial gunnery runs.

4.2 Prior Environmental Activities

The most important UXO remedial actions of relevance to this demonstration were those conducted in the 1972 clearance before the property passed from Navy control to the Army Corps of Engineers. This operation began with a surface clearance of ordnance and metallic scrap.

The area was then reported to have been plowed using bulldozers with 8-foot plows, and the newly exposed ordnance was also removed. These actions revealed the extensive distribution of rockets and bombs that had been either dropped or fired onto the range. The clearance report states that all of the 2,287,000 pounds of ordnance recovered during this clearance was subsequently reburied in 10 burial pits on various parts of the range, which were dug for this purpose.[20]

4.3 The Currituck Sound

The Currituck Sound is a relatively large body of water, stretching for about 3 miles east to west on the western side of the former range. The nearest outlet to the ocean is more than 30 miles to the south at Oregon Inlet. The bay is supported by a relatively large area of wetlands, creeks, and small rivers to the west and north; the water is only slightly brackish and supports substantial populations of both salt water and fresh water marine live (including blue crabs and large mouthed bass). Typical tidal swings are only a few inches; however, strong north or northwest winds may lower the water level by up to 3 feet in the winter and spring, sometimes moving the shoreline by more than 100 ft. The Sound is the wintering ground for large flocks of both geese and swans with flocks often numbering in the thousands along the shoreline. The eastern shoreline is typically characterized by wetlands with sea grasses extending out to water depths of a foot or so. The water is typically so murky (because of silt and very fine sand) that vegetation does not extend to deeper waters along the eastern side of the Sound.

On the right of Figure 4-3 is shown a modern satellite image of the former range. On the left is shown a Digital Elevation Model of the part of the Sound that we surveyed with the MTA magnetometer array. The DEM was constructed from depth sounding measurements made as part of the MTA survey. The water depths in the Sound remain very shallow ~1.4 m for a distance of 150-200 meters from the shoreline. The bottom sediments in these areas are very soft silt (~0.3-0.5 m deep). The water depth then fairly abruptly increases to 2.5-3.3 m. There are undulations in the bottom; however, for the most part the bottom is fairly flat. Over most of the Sound, except for near shore or near islands, the bottom sediments are fairly hard sand.

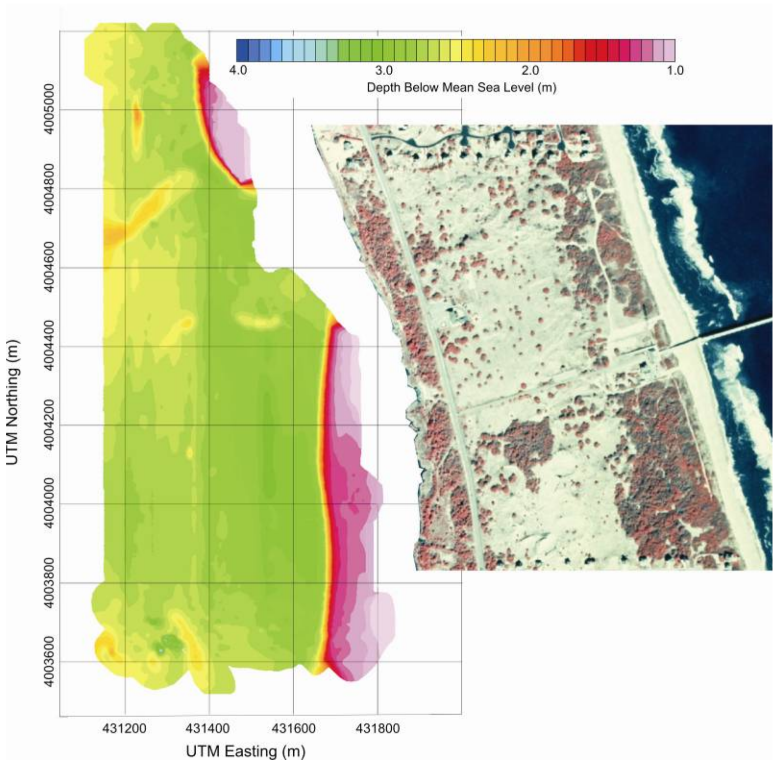

Figure 4-3. A modern DOQ photo of the former target range is shown on the right. Rows of beach houses (black squares) have been built at the north and south borders of the former range. A DEM is shown on the left of the part of the Sound that was surveyed.

4.4 Survey Logistics

There was only one usable boat launch ramp within 5 miles of the survey area. This was at the Duck Water Sports Marina in the Town of Duck. This marina supported Jet Ski rentals and had slips for a limited number of small boats. The water was very shallow in the marina area and along the channel into the Sound. It was not possible to enter or exit the marina with the MTA system except during relatively high water. Additionally, the narrow channel (lined with posts) made it impossible to navigate the channel with the pontoon boat (towing the platform) without assistance when the wind was from the north or south. See Figure 4-4. For this reason, the marina was used only to launch and recover the MTA. During the entire survey, the system was moored at nights to floats and pilings near the pier at the Sunset Grill a few hundred meters south of the survey area, Figure 4-5.

This pier at the Sunset Grill, Figure 4-6, was an excellent staging point for the survey because access to parking and the vessels was easy and because the mooring point was only about a 10 minute ferry from the survey area.

4.5 The Survey

The UXO survey took place over a period of 9 survey days in early May, 2005. More than 80% of the survey area was covered during the final three survey days. At the beginning of the survey period, equipment malfunctions limited survey time. High winds (rough water) limited survey time on two days. Slightly more than 150 acres were surveyed using the magnetometer array and a bit more than 50 acres were covered with the EM array.

Figure 4-7 shows a top level view of the anomaly image map from the magnetometry survey. For perspective it is displayed beside an orthophoto of the impact range. The highest concentration of metallic anomalies was found close to the shore directly west of the impact target. Small numbers of anomalies were still present at the western edge of the survey area, about 2,000 feet west of the shore line. About 500 targets were analyzed as potential UXO. 100 targets were recovered by UXO dive teams. Targets that analyzed with burial depths of greater than 1.5 ft and with sizes equivalent to or smaller than a 5 in rocket were excluded from the dig list.

Attempts were not made to recover larger targets because exclusion zones would have required closing the highway and evacuating the police and fire stations and the Army Research facility. As shown in Table 4-1 almost 50% of the recovered targets were ordnance or ordnance components. The non-ordnance recoveries were primarily (parts of

Figure 4-4. The dive boat is shown assisting the return of the MTA vessel to the North Duck Water Sports dock.

Figure 4-5. The MTA equipment is shown moored at the Sunset Grill dock about 250 meters southwest of the survey area.

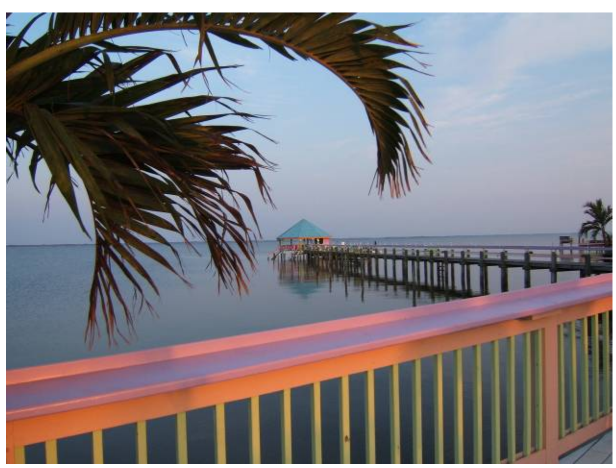

Figure 4-6. This image shows part of the boardwalk and the pier at the Sunset Grill restaurant. The MTA was moored just beyond the end of the pier in the evenings.

or intact) crab traps, boat anchors, and other ferrous scrap. All ordnance materials were consolidated at a prepared area on the Field Research Facility. They were challenged with one inch diameter shape charges after burying them with three layers of sand bags and with loose sand. The demolition charges showed that all recovered ordnance were inert or empty.

Table 4-1. Summary of Target Recoveries Made on the Currituck Sound

Ordnance/Ordnance Related Targets		Not-Ordnance Targets	
Identity	Number Recovered	Identity	Number Recovered
Mk 23	8	Crab Pots & Parts	24
SCAR	15	Boat Anchors	5
2.75" W.H.	7	Other Ferrous Scrap	26
BDU33/M76	5		
100lb Bomb	1		
75mm W.H.	1		
Zuni W.H.	1		
Fins/Rails	7		

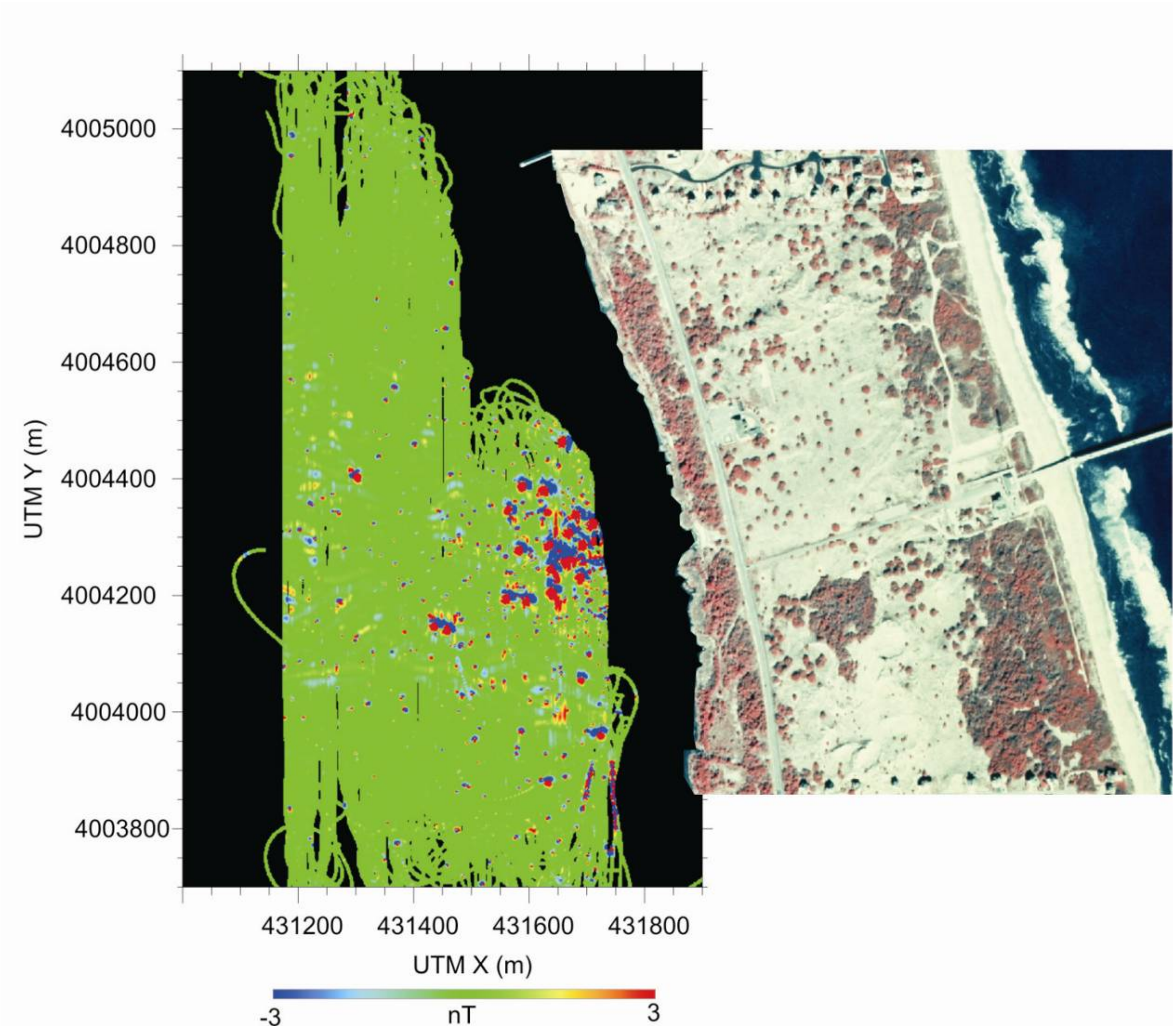

Figure 4-7. Magnetic anomaly image map of the magnetometer survey. A portion of the 1993 DOQ of the FRF is superimposed.

5.0 The Former NAD-Puget Sound

5.1 Site History

The second demonstration of the Marine Towed Array (MTA) took place (June 12-30, 2006) on Ostrich Bay (Puget Sound) adjacent to the current Jackson Park Housing Complex and the Naval Hospital Bremerton. NAD-Puget Sound has an ordnance history stretching back more than 100 years. The "Archive Search Report," published in 2002 succinctly describes the site evolution.[21] The Naval Ammunition Depot was established in 1904 and decommissioned in 1959. Ostrich 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 off loaded between three piers and lighters (powered barges). Assembled ammunition was reloaded onto the shallow water barges for transport to deep water where it was subsequently loaded onto Naval ships. Activity was

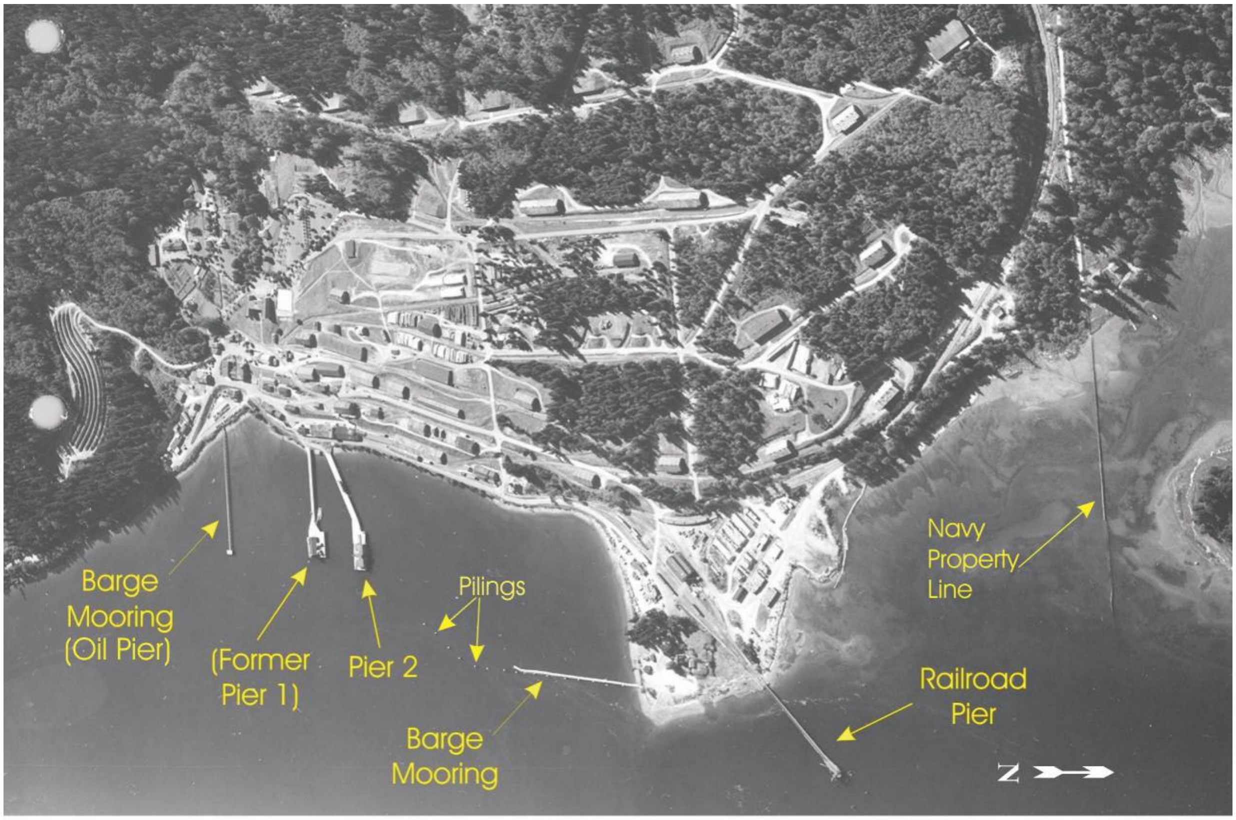

Figure 5-1. A part of Ostrich Bay adjacent to the Naval Ammunition Depot Puget Sound is shown during the period of its peak operation. All the labeled features except Pier 2 were removed prior our survey. Wooden fender pilings also surrounded the working areas of Pier 1 and Pier 2. When all the pilings were removed, some of them were broken off (above the bottom surface) rather than being removed.

particularly intense during the latter part of WWI and all during WWII. Figure 5-1 shows an aerial photograph from the 1940s of the NAD-Puget Sound facility.

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.

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.[22] The NAD has subsequently been replaced with a high density Naval housing community and a hospital, the Naval Hospital–Bremerton. Figure 5-2 shows a modern aerial photograph of the same area shown in Figure 5-1 (from ~50 years earlier).

Figure 5-2. Modern aerial photograph of the JPHC and the NHB. The red line marks the Navy property boundary. The blue line marks the approximate marine Navy property boundary at 4 fathoms below MLLW.

5.2 Prior Environmental Activities

Since 2004, 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.[22] The lands under Ostrich Bay beyond the Navy property line are the responsibility of the State of Washington.

In association with the Remedial Investigation studies that began on the Bay in 2004, 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 to be conducted on the Bay were 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.[23]

5.3 Ostrich Bay and the Sound

Figure 5-3 shows a relatively modern (uncorrected) aerial photograph of the Ostrich Bay area, which also includes a larger perspective of the other nearby Puget Sound features.[24] Ostrich Bay lies near the end of this local chain of bays and inlets in the sound system. Oyster Bay is at the end of this chain of bays. Tidal swings vary between 10 and 14 feet (depending on the lunar cycle and seasons). This creates large currents in restricted areas (up to 5 kts) such as in the Port

Figure 5-3. 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.

Washington Narrows and past Madrona Point between Ostrich Bay and Oyster Bay. This whole area (including Seattle) lies near sea level between the Olympic and Cascade Ranges. The overall geology was created by mountain building and volcanic events. The area is still very geologically active. Ostrich Bay has a relatively rugged shoreline (at high tide). At low tide the beach areas are a combination of mud and shell with rocky outcroppings. Ostrich Bay is reported to be accreting sediment at the rate of ~1cm per year. This is apparently dependent upon the local tidal currents, however. In our magnetometry surveys, areas north of Madrona Point along the eastern shoreline of the Bay are strongly geologically active. Other areas of the Bay (particularly the southern part of the Bay) are relatively magnetically inactive, typified by relatively deep homogeneous silt accumulations. Figure 5-4 shows a DEM of Ostrich Bay. This map was constructed based upon bathymetric studies recently conducted by Tetra Tech EC as part of the RI.[25] The deeper areas (between 35 and 40 ft) are located south and east of Erland Point. The northern and center part of the bay appear to be rough, characterized by both stones and depressions. The features that extend above the background level are mostly smaller than 1.5 ft high. Larger boulders are observed off Erland Point and along rocky areas of shoreline. Very fine scale examination reveals the numerous broken off pilings and sunken pilings lying flat on the bottom.

The dredge cut areas around Pier 2 remain at least 15 ft deep.[25] Figure 5-5 shows more detail. The former dredge cuts associated with Pier 1 and the Railroad Pier have been filled in to above grade level. The southern one-third of the bay has bottom sediments consisting of soft silt. The southern and southeastern shallow water areas have numerous off-shore moorings for small, medium, and large boats. The northern half of the bay tends to have bottom sediments consisting of hard mud, shell, and gravel/rocks. There are some areas with larger rocks (approaching boulder size, >3 ft). These tend to be off shore from rocky outcroppings that are visible on shore.

The weather in May is mild, with cool mornings and warm afternoons. There is typically very little rainfall at this time of the year and winds are usually light. During this survey, rough water was not a problem. Water visibility was typically four to six feet, Figure 5-6.

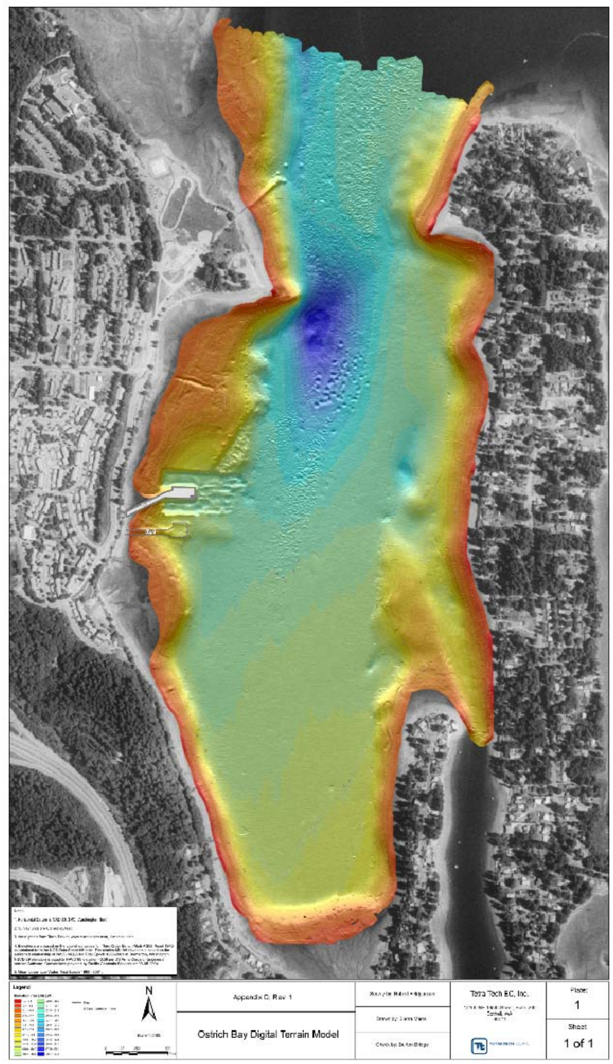

Figure 5-4. A false color bathymetric image of Ostrich Bay is shown overlaid on a recent aerial photograph of the area. The deepest area of the Bay (blue) is ~40 feet at low tide.

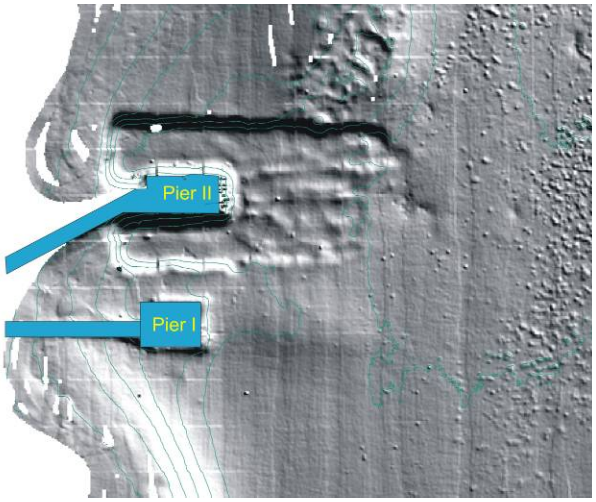

Figure 5-5. A bathymetric image of the bottom structure around Pier I and Pier II is shown.

Figure 5-6. The MTA platform is shown surveying along the Ostrich Bay southwest shoreline in shallow water.

5.4 Equipment Transport and Local Logistics

The MTA equipment was transported from North Carolina to Seattle using a 45 ft flatbed trailer. With a standard height trailer, the wheels have to be removed from the MTA boat trailer to remain under the 13.5 ft overall height limit. The sensor platform was loaded onto the deck of the pontoon boat, Figure 5-7. The tow cables were shipped in a wooden palletized crate. The other equipment was packed into 4 X 4 ft plastic shipping containers. A few items such as the tow point assembly were Figure 5-7. secured directly to the deck of the trailer. There are no accessible loading docks or marinas with large strap lifts near Ostrich Bay; therefore the equipment was transported to the Shilshole Marina in downtown Seattle. Consequently, the initial staging took place at the marina in Seattle. See Figures 5-7 to 5-9. The boat trailer was

Figure 5-7. All of the MTA system components were shipped on the deck of a single 45 ft trailer. The sensor platform was transported on the boat deck.

Figure 5-8. A marine hoist was used to unload the MTA vessel and the trailer together. It is difficult to lift the vessel alone without damaging the pontoons.

reassembled and removed from the trailer. The pontoon boat was launched at the marina. The remainder of the containerized equipment was loaded into a rented box truck and the sensor platform was loaded back onto the pontoon boat trailer.

The Shilshole Marina, which has excellent boat launch ramps, is about 20 miles from Silverdale by water and about 50 miles from Silverdale by highway. 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. The box truck and a rental SUV (towing the boat trailer) were driven to Silverdale where the sensor platform was assembled, Figure 5-10, and mated with the MTA tow vessel on June 18 in preparation for surveying.

A small boat was leased from a local marina (Figure 5-11) for the duration of the survey. It was used as a chase boat and to transport workers to and from the work site.

Two moorings were set south of Pier 2 and were used to moor the pontoon boat and the sensor platform overnight during the survey operations. This mooring arrangement is shown in Figure 5-12. The chase boat was used morning and night to ferry the MTA crew to and from a local marina about 3 miles away from the work site.

Figure 5-9. A large forklift was used to unload the sensor platform and later load it back onto the MTA vessel boat trailer.

Figure 5-10. The sensor platform is being assembled in the parking lot at Silverdale Marina.

Figure 5-11. The chase boat is shown being launched at Silverdale Marina.

5.5 The MTA Survey

Surveying began on 18 June with the Prove-Out-Site and the Calibration Lane, which had been prepared by NAVFAC Northwest and the NEODTD using inert ordnance items typical of those previously recovered from around Pier 1 and Pier 2. The actual magnetometry survey of the Bay took place between 19 and 27 June, 2006. During this period ~220 acres of the Bay, extending to the Navy property line in Dyes Inlet were surveyed, Figure 5-13. Based upon the survey files, about 65 hours of survey data were collected. Figure 5-14 shows a top level image of the anomaly image map for the magnetometry survey superimposed on a modern orthophotograph of Ostrich Bay.

Survey data were processed daily to maintain quality control and to allow resurvey of areas, as required. A total of 633 magnetic anomalies deemed to possibly be ordnance were analyzed and categorized into groups based upon their probability of being ordnance. These analysis spreadsheets were provided to NAVFAC Northwest and EPA Region 10. They jointly chose a list of 106 targets for investigation that were widely distributed about the survey area. One hundred of these targets were investigated by Navy EOD divers from the Bangor Det. Seven of the investigated targets were declared to be MEC or MEC-related objects. All of the MEC and MEC-related targets were located in the near vicinity of Pier 1, Pier 2, or the Railroad Piers.

Figure 5-12. The MTA vessel and sensor platform are shown moored on the south side of Pier II.

Figure 5-13. The Marine Towed Array is shown surveying on Ostrich Bay.

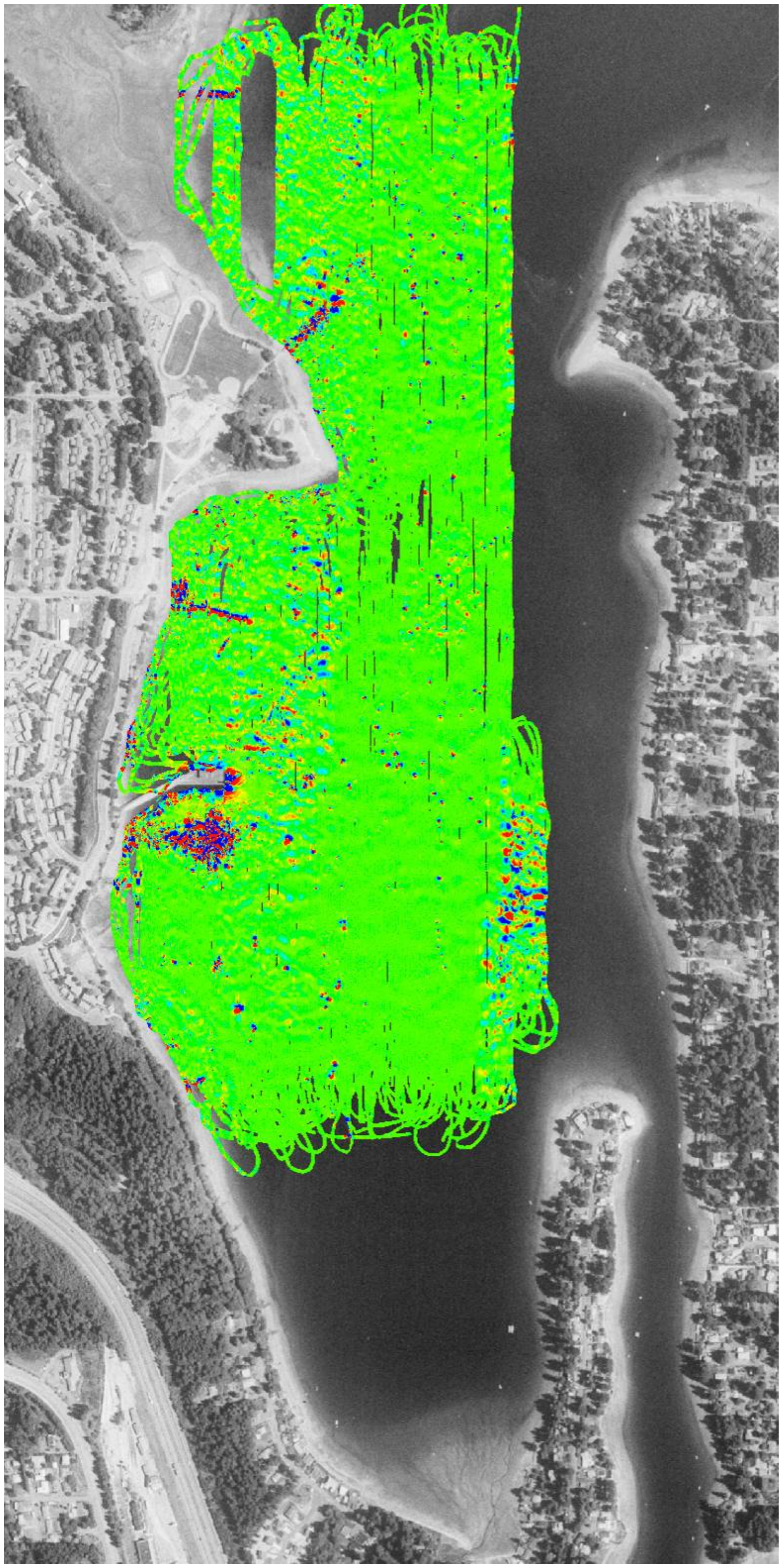

Figure 5-14. The MTA magnetometer survey is shown superimposed on a recent aerial photograph of Ostrich Bay.

6.0 The Former Erie Army Depot

Camp Perry was established in 1907 by the state of Ohio for the training of the state National Guard. Physically, it is located in rural Carroll Township, Ottawa County, OH, on Lake Erie, approximately 37 miles east of Toledo and 6 miles west of Port Clinton. Part of the camp was used to establish the Erie Army Depot in the spring of 1918. During the next 2 years, the site was equipped to proof fire (verify that the cannons will withstand the pressure of firing) thousands of pieces of artillery.[26]

Between World Wars I and II, the site was less active and was used primarily to warehouse and issue various items of ordnance. In 1941, the artillery test firing mission of the site was reactivated in support of World War II and the name of the facility was changed to the Erie Proving Ground. During the subsequent 5 years, 70 percent of the mobile artillery used by the U.S. Army or provided to Allied armies was proof-tested and accepted at Erie Proving Ground. Between 1946 and 1951, the site reverted to a peace-time role and was renamed the Erie Army Depot. Late in 1951, the depot assumed the additional roles of anti-aircraft support testing and the overhauling of surface-to-air guided missiles (in support of the Korean Conflict). Additional activities included logistical support to the Regular Army and National Guard anti-aircraft units training at Camp Perry.[27] Test firings of Vietnam-era munitions continued into the early and mid-1970s. The mission of the Camp Perry Ordnance Office continues today as a test and training range for small arms.

The Erie Army Depot and the impact areas associated with its ranges were designated by the United States Government as a Formerly Used Defense Site (FUDS) under the Defense Environmental Restoration Program (DERP).[26,27] The property, which was formerly used for artillery, testing and mortar and small arms training, established impact areas both on land and northward into Lake Erie extending almost to the Canadian Border. Ordnance and explosive waste (OEW) and potentially live or unexploded ordnance (UXO) have been found on the lake bottom, in the Federal navigation channel in the Toussaint River, in the marshland adjacent to the firing ranges, and along beaches fronting the former Depot.[28-30] The impact areas associated with the various ranges were located on, near, or offshore of the FUDS beaches adjacent to Lake Erie. Several different range fans have been described that were associated with different types of ordnance operations. Figure 6-1 shows the areas of the Lake that were associated with the off shore range fans. The cross-hatched part of Figure 6-1 (labeled Area III in the figure) is still reserved as a small arms impact area. The total impact area associated with all of the offshore range fans is in excess of 95,000 acres.

Proof testing of projectiles and the gun barrels that were designed to fire them took place from 15 fixed gun emplacements located adjacent to one another in an east-west line about 2,000 meters inland from the beach. The orientation of the gun emplacements, the orientation of the observation booths, and the locations of the “target posts” are all consistent with the weapons being fired directly north into the Lake. Apparently, the guns were aimed to fire projectiles at the top of the various target posts; observers (above and behind the firing stations) could observe the projectiles from the time they left the gun barrels to the firing posts and evaluate the performance of the gun barrels and the projectiles.

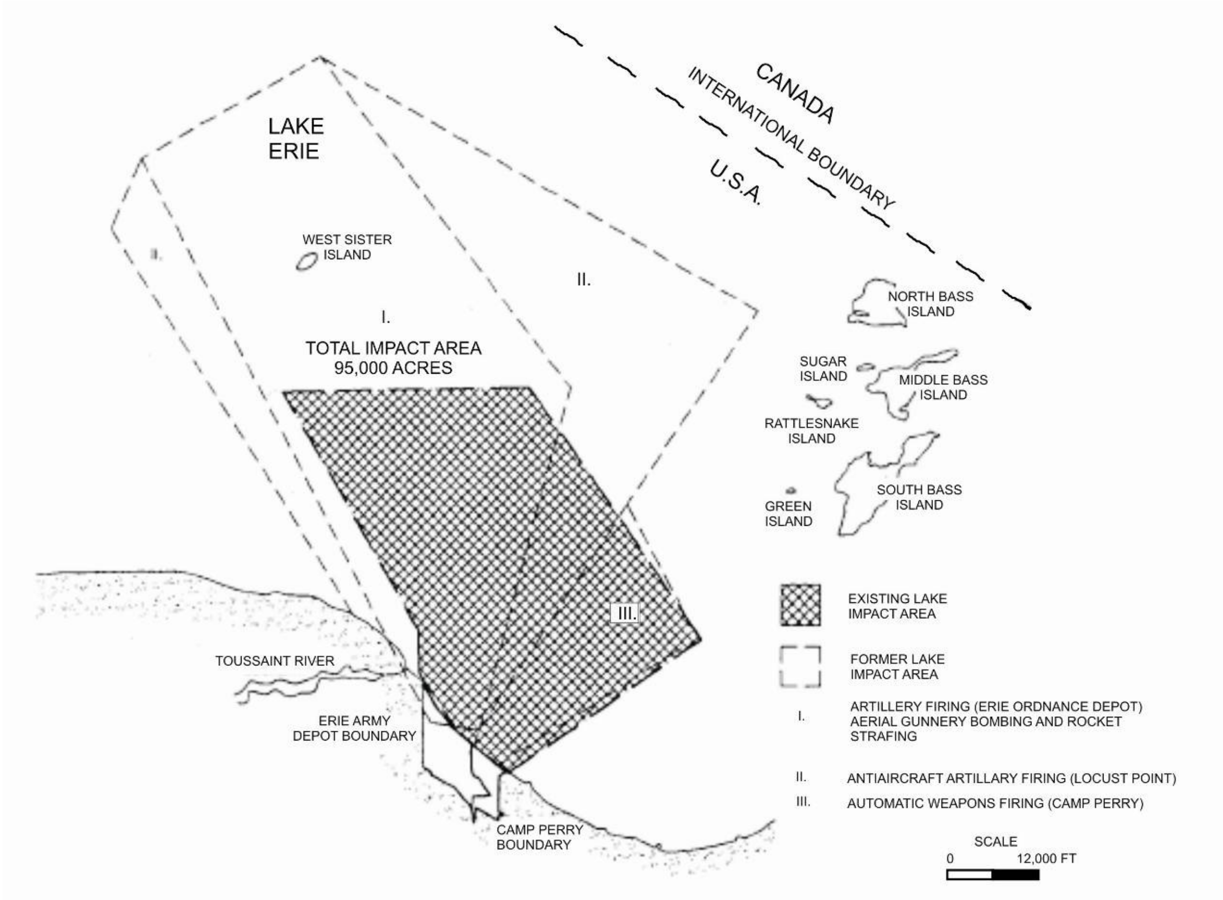

Figure 6-1. Estimate of the historical impact areas in Lake Erie. Figure adapted from Reference 27, Appendix L.

OEW and UXO have been found on the beach and during the 1991 dredging operations for the Federal navigation channel at the Toussaint River, which were conducted by the USACE District, Buffalo.[28] Ordnance found on the shoreline appears to be mobile and likely originated from offshore.

6.1 The ESTCP Pilot Program

In FY06, ESTCP was directed by Congress to conduct work to characterize UXO contamination impacting the Toussaint River and parts of the Lake associated with ordnance testing that may affect the shoreline and the river. The specified operation was conducted in accordance with the recommendations of the Defense Sciences Board.[8] An objective of the ESTCP pilot program was to use technologies suitable for wide area assessment (WAA) of suspected munitions-contaminated sites to address the issues associated with future site characterizations and possible cleanups.[31]

Figure 6-2 shows a NOAA marine chart with the defined investigation boundaries that were associated with the planned ESTCP pilot program. The primary survey area is bounded in red. The part of the red-bounded area that lies within the various impact range fans (Figure 6-1) is shown bounded in blue. A possible extension to the primary survey area is shown bounded in

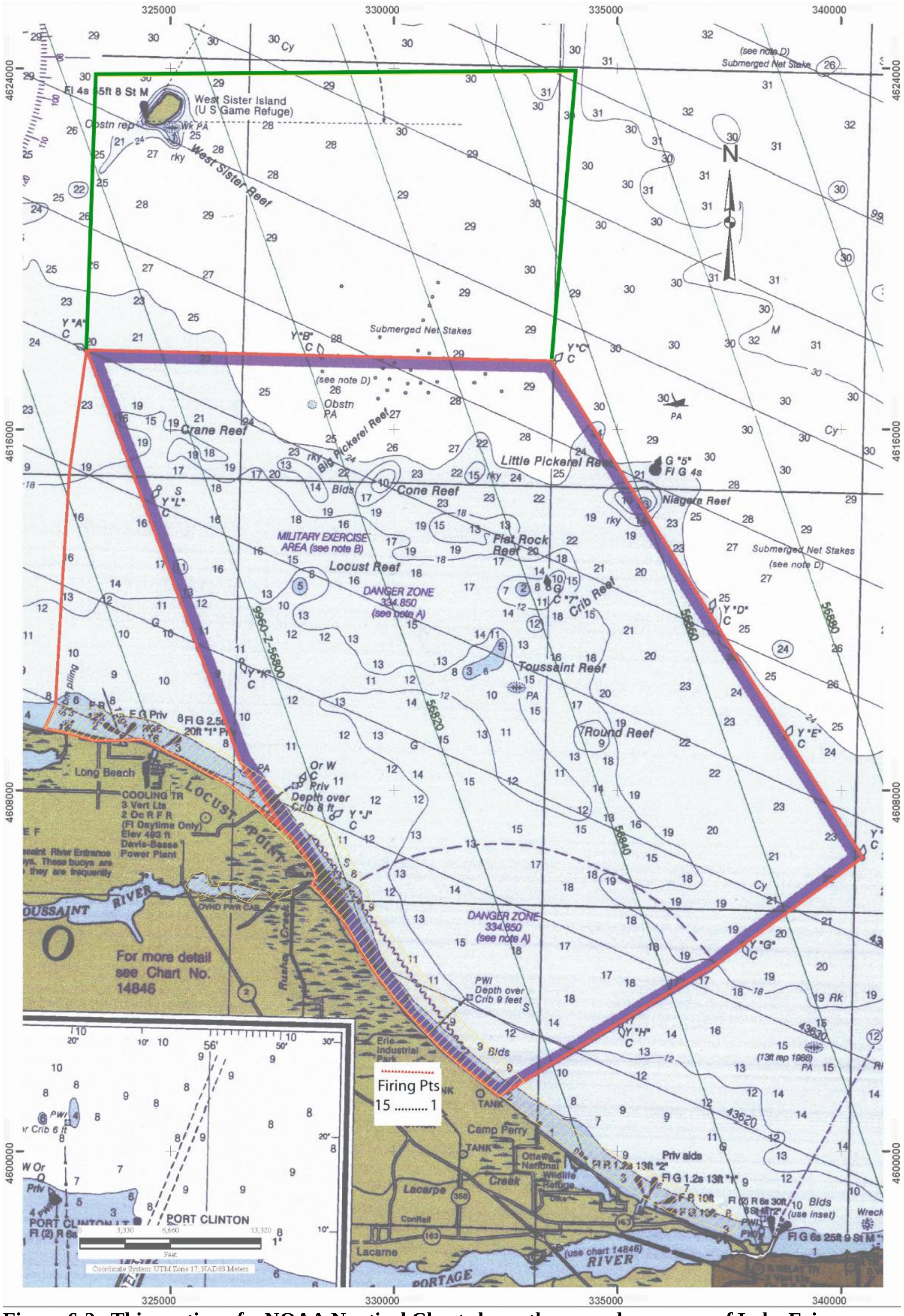

Figure 6-2. This portion of a NOAA Nautical Chart shows the near-shore areas of Lake Erie adjacent to the former Erie Proving Ground.

green. The area bounded in green also is completely contained in the range fans defined in Figure 6-1.

6.2 Lake Erie and the Toussaint River

Lake Erie is fairly shallow; in the area shown in Figure 6-2, the water depths (in general) gradually increase to ~30 ft at the northern boundary of the defined survey area. A series of shoals occur across the mid section of the survey area. These shoals are referred to in the marine chart (and by the local residents) as reefs. The reefs are relatively shallower areas, which slowly rise from the general background water depth to flat submerged peaks. The northern most of the reefs (the West Sister Reef, rises several feet above the surface to form an island (West Sister Island). In general the reefs are gravel or rocky outcroppings that rise above the hard mud and sand (and shell) bottom that characterizes much of the rest of the Lake. Some areas, particularly near the shore (and around West Sister Island) have bottom sediments that are mainly silt and soft mud. The information about the bottom structure became apparent during the diver investigation phase of the study. The contours marked in Figure 6-2 are at 1, 2, 3, 4, and 5 fathom water depths.

The study area is located along the south shore of the western basin of the Lake. The land is a low, flat, broad plain, founded on lacustrine (lake) clays deposited during interglacial periods when the predecessor of the modern Lake Erie was much larger. The eastern boundary of the study area is Camp Perry, which is under the command of the Ohio National Guard. The western boundary of the study area is the Toussaint River. Along the northwest shore of the Toussaint River is a section of the Navarre Division of the Ottawa National Wildlife Refuge and the Davis-Besse Nuclear Power Station. The beach is a narrow, shallow depth, sandy barrier which includes washover deposits and evidence of breaching; in many areas the back beach consists of a thin boundary of scrub and woodlands. The FUDS shore has a history of rapid erosion. Beach erosion rates have averaged almost two feet per year since before 1900. Rubble-mound revetments have been added as shore protection at the southeastern end of the study site through the Camp Perry boundary and fronting approximately 0.8 km (0.5 mile) of the central beach.

The western end of Lake Erie is shallow and subject to rapid water level fluctuations as storms and frontal passages can "set up" or seiche both the local and entire lake water surface. This process is an important contributor to the character of the study site. During the period of the MTA survey, on several occasions west or northwest winds of 10-20 mph blowing continuously for two days or more lowered the Lake water level by more than 30 inches. This caused us to cycle our overnight mooring operations among three different marinas during the survey. When the water is at the lowest level, our access to the lake (from the Beef Creek Marina) was blocked at the mouth of the Toussaint River by shallow water. When the Lake is refilling, often the water flow in the Toussaint River is reversed as the Lake rises. When east winds pile up water in the Lake, we could not use Wild Wings Marina because the clearance at a road underpass was too low for the pontoon vessel to pass.

Another process important to this site is the annual winter formation and movement of lake ice. The western basin of Lake Erie is usually the first portion of the lake to develop a solid ice pack. The ice sheet usually encases the south shore, including the study area Lake ice can both isolate the near-shore bottom and the beach from wave forces or (particularly during ice breakup) can act as a tool, increasing the damages of the waves. Ice damage to shore developments is common in the Great Lakes. However, the effect of the moving and stacking ice sheet on bottom sediments and shore erosion is a poorly characterized phenomenon, particularly as it relates to sediment (and object) transport. It is a widely accepted conjecture that the winter ice sheet (particularly where the water is shallow enough that the ice extends to the sediment surface) is a source of ordnance transport to the beach during the spring ice breakup.

We initially chose the Beef Creek Marina to launch the MTA and to park the system at night. This is a small marina with about 40 slips and a modern boat launch ramp. As shown in Figure 6-3, the marina is about 200 meters from the point where Beef Creek empties into the Toussaint River. This location was chosen because it is very near the lake and central to the survey area. The Toussaint River is claimed to be a dredged and navigatable waterway, Figure 6-4. The dredged channel is marked within the river and a corresponding 250 ft wide channel is marked for several hundred yards into the Lake. Because of revetments and rip-rap installed

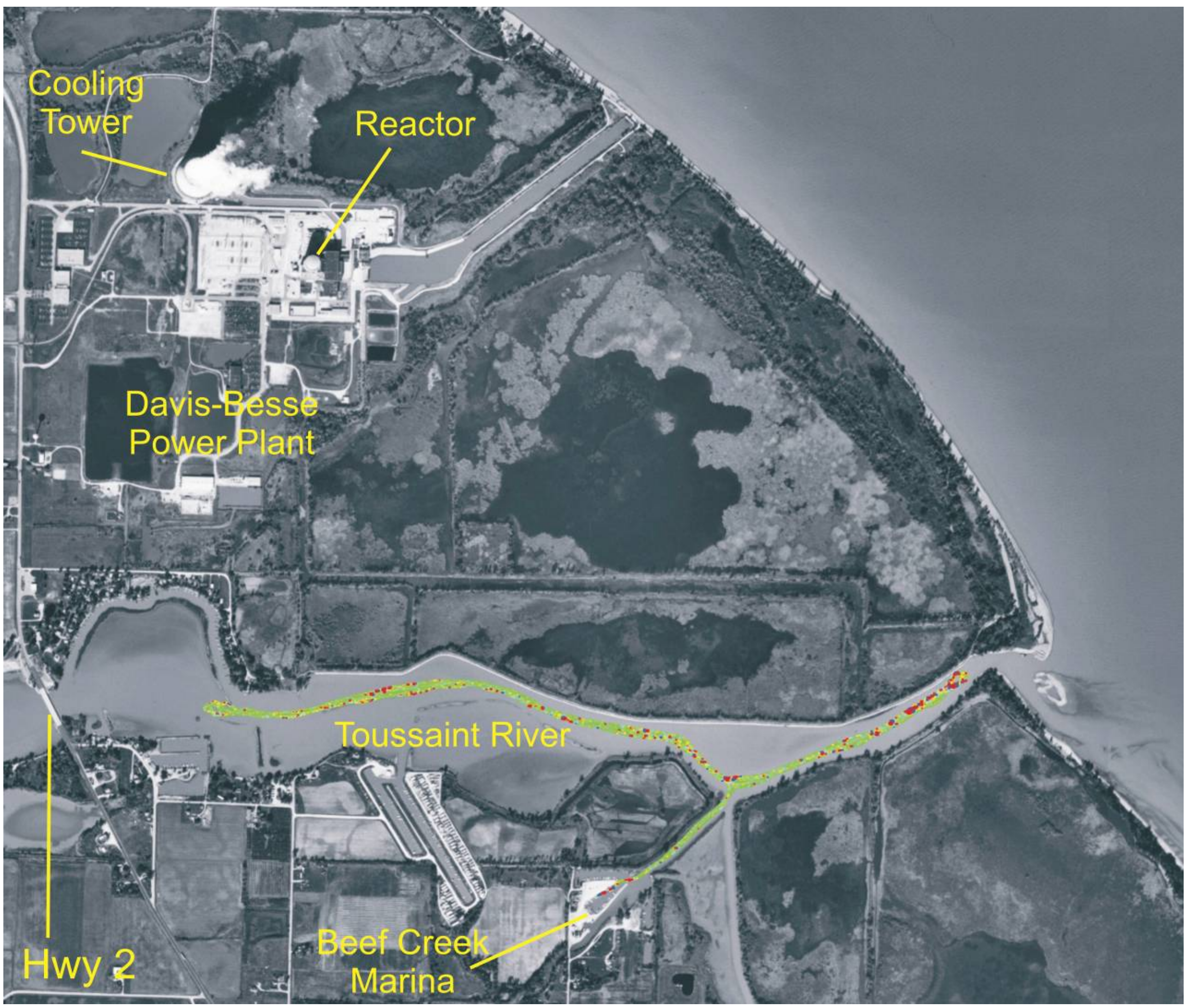

Figure 6-3. This 1996 aerial photograph shows the Toussaint River and the Davis Besse Power Plant. The magnetic anomaly image map of the MTA river survey is shown superimposed on the photograph.

along the shoreline on the Davis Besse property, sand is forced to drift northwest-to-southeast across the mouth of the river. When the Corps of Engineers last officially dredged the mouth of the river it was claimed that MEC was found in the spoils. The Corps has not officially allowed the river mouth to be dredged again and they have refused to allow local groups to reinforce the mouth of the channel to stop drifting sand from filling the channel. Even without permits, the local marinas and boat owners have a private dragline dredge on a barge in place at the mouth of the river that is used to keep a channel open for pleasure boats to pass.

Figure 6-4. The MTA survey boat is shown approaching the mouth of the Toussaint River. Note the red and white channel marking buoys.

During the early part of the MTA survey we observed that the water level rose and fell by more than a meter. After several days of strong west winds, the water level was reduced so much that access or egress through the Toussaint River to or from the Beef Creek Marina was not possible. During these periods, the survey vessel and the sensor platform were moved several miles to the west to the Wild Wings Marina where the Lake access channel is deeper. During the periods of lowest water, our equipment was also stranded in the Wild Wings Marina. Following periods of very low water, when the wind lies, the lake level takes about 1 day to return to its average height. During periods of rising or falling water levels, the water flow in the Toussaint River is quite strong, with currents perhaps in excess of 3 knots in narrower parts of the river. During periods of average lake height we measured water depths in the dredged channel of the Toussaint River. They range from ~1.2 meters near the mouth of the River to 2.5 meters in wider areas of the river where the shoreline is reinforced with rip rap. The dredged channel width varies widely from as little as 2 meters (on occasion) at the mouth of the river up to perhaps 30 meters wide where Beef Creek and the Toussaint River merge. The depth of the channel becomes so shallow about 250 meters south of the Highway 2 Bridge that the boat and the sensor platform cannot navigate farther up the river. Because the entire channel is relatively shallow and very narrow, the tow cable length was reduced to 8 meters to survey the channel. Six passes were made to provide coverage of most of the dredged channel area.

6.3 Equipment Transport

During the week of 7 August, 2006 all electronic and mechanical components of the MTA were exercised and secured for shipment to Port Clinton. System spare components were checked against inventory and secured for transport. Tool boxes, system spares, and repair hardware were sorted and packed for shipment to support the field operation. All packing containers were inspected and compared to the equipment inventories pasted on the sides of the boxes.

A pickup truck and a 14-foot box truck were rented from agencies in North Carolina to support the field operation. All pack out operations were completed on 11 August; the support equipment was packed and stored in the box truck. The two vehicles were used to tow the pontoon boat and the sensor platform (on separate boat trailers) from Cary to Port Clinton on 14 August.

The AETC staff was joined on 14 August by Mr. Osborne of EOTI, who transported the chase boat to the site. The pontoon boat was outfitted and prepared for launch, Figure 6-5. The sensor platform was assembled adjacent to the launch ramp, Figure 6-6, and launched beside the pontoon boat in an adjacent ramp. The two components were moved to adjacent slips in the Beef Creek Marina and moored beside the chase boat, which occupied a third slip. The room in the marina was so restricted that the sensor platform had to be moved into and from its slip by a diver to avoid damaging the tow cable or to avoid collisions with other vessels.

The sensor platform, Figure 6-7, is shown lying very low in the water. This was because entering the channel into the Toussaint River (and from the Toussaint River into Beef Creek) the water was so shallow that the platform always bumped along the bottom and collected mud into its internal cavities. This mud, which typically washed out once we were underway in the Lake, often made it difficult to exit the very narrow and shallow channel from the Toussaint River into the Lake.

Because there were no sheltered areas in the river or the lake to moor the MTA equipment, it had to be moored overnight in slips in various pleasure boat marinas. As mentioned above, we moved back and forth among three different marinas during the survey depending upon the water levels in the lake and the distance to the survey area that we were working at a given time.

Figure 6-5. The pontoon boat is shown on its transport trailer at the Beef Creek Marina.

Figure 6-6. The sensor platform is assembled on its boat trailer, the tow cable is coiled up on top of the platform and it is launched beside the pontoon boat for mating.

Figure 6-7. The sensor platform, the tow vessel, and the chase boat are moored in three adjacent slips.

6.4 The Survey

The master survey plan called for surveying a series of widely-spaced transects within the area outlined in Figure 6-2. The intent was to sample the area of the various offshore range fans to establish the pattern of UXO contamination and to determine the relative density of ordnance across the marine site. In addition, the channel in the Toussaint River was to be surveyed using the MTA, from the mouth of the river to the upriver extent allowed by the water depths.

Figure 6-8 shows the planned survey transects as black lines. The survey plan called for surveying alternate transects starting at the shoreline at the south limit of the site. The actual transects that were surveyed are shown in yellow. The magnetic anomalies (specified by the automated target picker) are shown as red diamonds superimposed on the yellow survey transects.

The area south of survey Transect 35 lies within the range fan of the small arms training area of Camp Perry. See the dashed curve arc in Figure 6-2. During training, the small arms are fired from fixed positions northward into paper targets located on top of a soil berm at the shoreline. The range is busy during parts of most days during the week. Survey schedules for the southern transects were coordinated with the Range Control Officer. These transects were primarily surveyed during the weekends.

Survey productivity on this site was seriously impeded by two causes (that were related to each other). The northern half of the survey area lies from 5-12 miles offshore from the marinas where the MTA was moored overnight. Transit times from the marina to the start of a survey transect line (and visa versa) could routinely be more than 1.5 hours on the more northern lines. The long ferry times were exacerbated when there were significant waves on the lake. Often ferry speeds to and from the survey transects were reduced to ~1.2 m/sec when wave heights exceeded 2 ft. Squalls and thunderstorms often would increase wave heights from 1 to 3 ft within 45 minutes to an hour. Even careful attention to marine weather alerts, were not sufficient to avoid being caught 10 miles off shore with wave heights increasing to levels that were not compatible with MTA operation.

The wave fronts typically traveled from west to east (or northwest to southeast). This required the survey vessel to plow almost directly across the waves during east to west surveys. Pitching over the top of a wave induces a jerking motion into the tow cable and tends to break weak links when the wave heights are two feet or higher. In subsequent surveys to this one this effect was reduced by introducing a 1 m flexible cable between the tow point and the hookup to the tow cable. The flexible cable was designed to stretch by 50% under 1,000 pounds tension. This significantly reduced the G-forces on the tow cable from pitching headlong over waves.

During the first half of the survey period, the weather was, in general, benign. The lake surface was sometimes even glassy calm. See Figure 6-9. During this period the primary survey delays resulted from having to change marinas because of the lake height, or from time lost to ferrying the platform to and from distant off shore sites. During the month of September and into the beginning of October, the weather became increasingly more problematic. During the first half of September, we were on the Lake approximately half the days. After September 15 (and until 13 October when all operations were discontinued) it was possible to survey on the Lake only two days (September 17 and September 21.

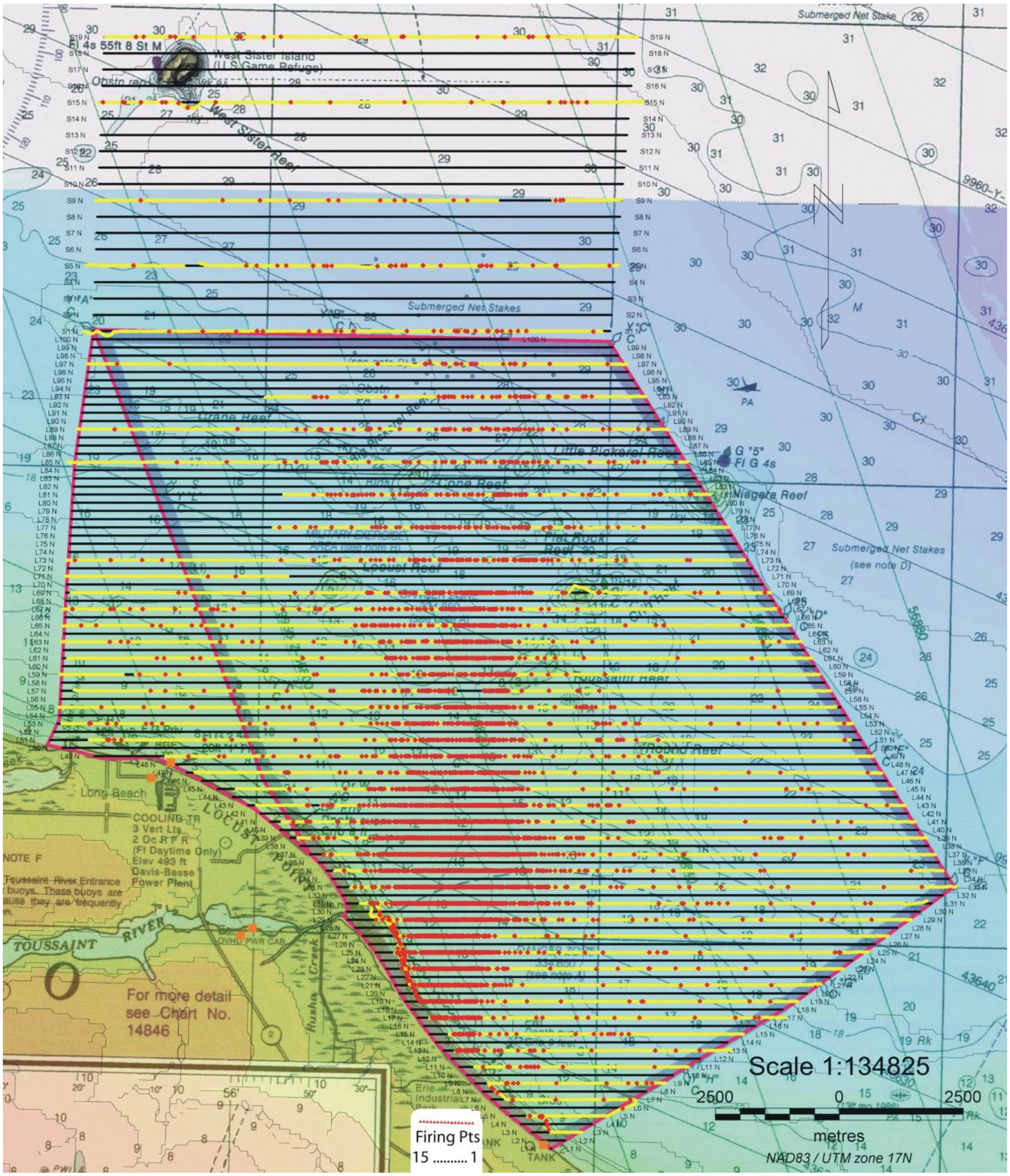

Figure 6-8. The planned survey transects (black) are shown overlaid on the NOAA marine chart. The 15 fixed firing points are shown at the bottom of the image.

6.5 Data Analysis

Figure 6-9. The MTA is shown surveying about 3 miles offshore from the Davis Besse Power Station.

Because the results of this survey were supporting a concurrent diver target investigation and recovery, target analysis of selected data areas was carried out during the data collection period. It was desired to diversely sample the targets in the survey area so data were analyzed in five separate areas as described below.

- All data in transects TR35, TR37, TR89, WS15, and WS 19 were analyzed. These data were chosen as typical of the survey area that fell within the impact range fans. They were all north of the currently active range fan so that divers could work without coordination with Range Control.
- All magnetic anomalies in the survey of the Toussaint River were analyzed.
- Selected areas offshore from the Davis-Besse Power Plant were analyzed. These were the only areas that were completely outside the known Range Fans.
- Selected transect areas above identified "Reefs" were analyzed. These areas are heavily used by fishermen.
- Several survey passes were made parallel to the shoreline between TR19 and TR31. These data were analyzed because they overlapped the area surveyed by the Airborne MTADS.

6.6 Target Investigations

Figure 6-10 is a representation of the partition between UXO recoveries (♦) and non-UXO recoveries (♦) among the 229 intrusive investigations that EOTI divers carried out. The areas and transects surveyed by the MTA are shown in yellow.

6.6.1 ***Areas Beyond the Range Fans*** Intrusive investigations were conducted on 28 targets within the Toussaint River. No UXO were identified. The majority of these investigations resulted in "No Finds" because the targets were buried so deeply in the mud that divers could not reach them. There were 11 intrusive investigations carried out offshore from the Davis-Besse Power Station. Recovered targets included 4 boat anchors and several pieces of (non UXO-related) metal scrap and metallic boat parts. The reported recoveries from this area likely represent the general background of indigenous clutter from non-ordnance related activities.

6.6.2 ***Areas Within the Range Fans*** Intrusive investigations were carried out on 189 targets within the Range Fans associated with the former training and proof testing activities. A summary of these investigations is provided in Table 6-1**.** Of the 141 intrusive dives in this area that resulted in positive identification of the targets, 117 intact ordnance items were recovered, and an additional 13 recoveries were described as fuzes, ordnance components, and/or shrapnel.

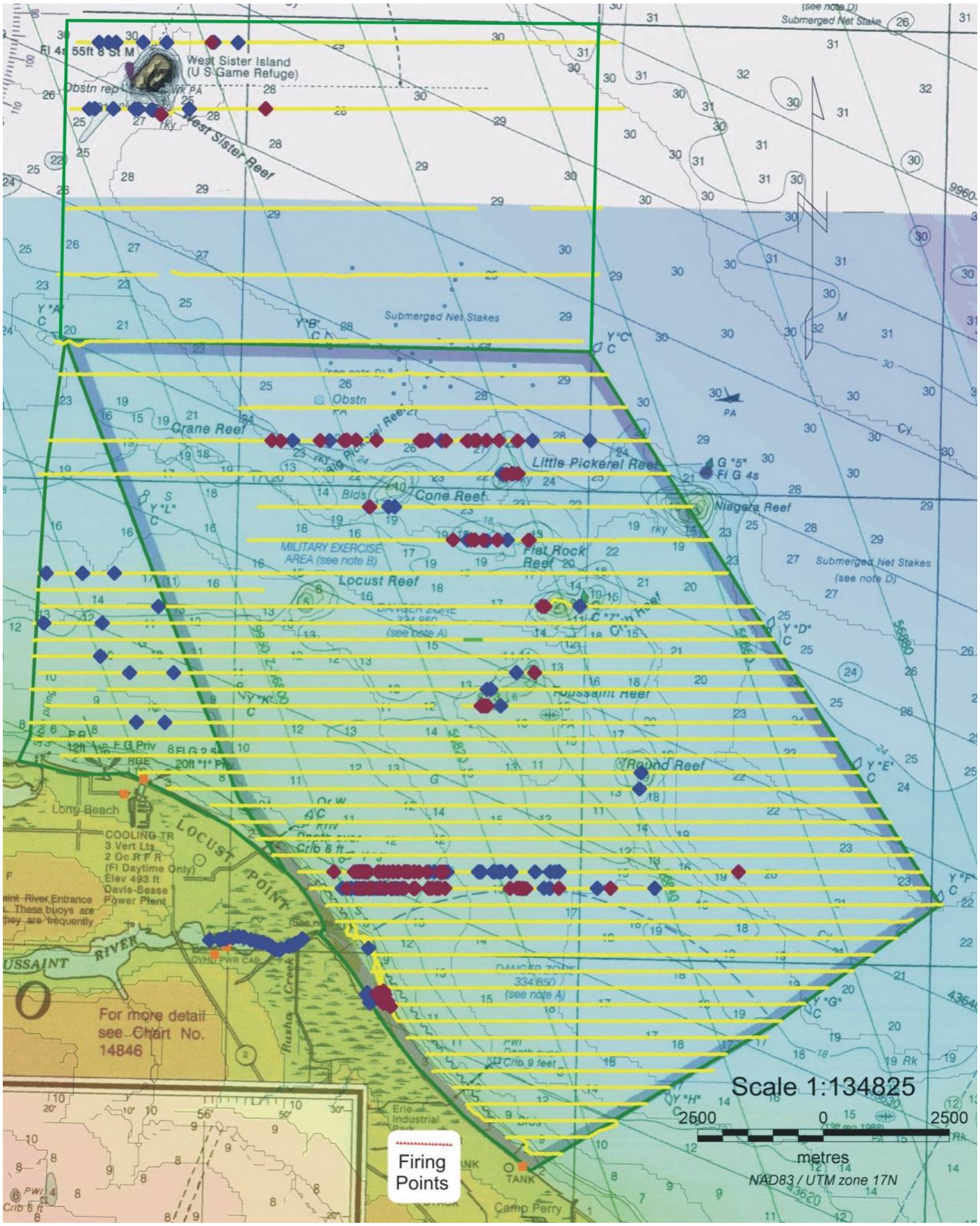

Figure 6-10. The UXO recoveries are noted as red diamonds; diver investigations for which no UXO was discovered are noted as blue diamonds.

Table 6-1. Summary of the intrusive investigations within the Range Boundaries

Recovery	Survey Area							
	Airborne	All Reefs	Tr35	Tr37	Tr89	WS15	WS19	Subtotal
155 mm Projo	7	10	18	25	16	2	1	79
105 mm Projo		3	1	3				7
90 mm Projo		2	4	7	2			15
75 mm Projo		2	1					3
57 mm Projo				1				1
37 mm Projo			2	2				4
4.2 in Mortar		1	4					5
2.75 in WH	2							2
250 lb GP Bomb						1		1
Fuze/Ordnance Components				2				2
Frag Recovery		1	8	1	1			11
Anomaly Not Identified/Too Deep/ Hot Rocks, etc.	4	12	6	7	3	7	6	45
Total Intrusive Dives	18	31	49	44	24	12	8	186

The mortars and the 2.75 in warheads were recovered close to shore and presumable were associated with onshore training activities. The one GP bomb recovered was immediately adjacent to West Sister Island. It is an outlier; it may or may not indicate that West Sister Island was ever used as an airborne drop target. It could have been an isolated drop by an aircraft returning to base after training activities associated with a different range.

6.6.3 ***Live Ordnance*** All of the 155 mm and most of the 105 mm projectiles that were recovered had their original shipping lugs in place. All recovered ordnance was challenged by 1 inch shaped charges in a series of demolition shots following completion of the dive work. There were no reported high order detonations during these operations, Figure 6-11. However, there were 13 instances, Table 2, where ordnance frag and/or fuzes were recovered by divers. Additionally, in the list of ordnance that was identified but not recovered, 15 projectiles and mortars were identified as being fuzed. They were left in place because they could not be recovered. In summary, it is apparent that both live and inert projectiles were fired into the Lake.

Figure 6-11. Recovered projectiles are being set up with shaped charges and sand bags for demolition.

7.0 Vieques

Vieques is a small island located approximately 10 miles east of the main island of Puerto Rico. It is 21 miles long east-to-west and is 3 miles wide with a total land area of 52 square miles. During the 1940's the U.S. Navy purchased 25,000 acres of land on Vieques on the eastern and western ends of the island.[32] The acquired land was used for Naval gunfire support and air-to-ground training from the 1940's until May, 2003. The western sector of the island was used for the US Naval Ammunition Support Detachment (NASD), while the eastern sector of the island was used as the Vieques Naval Training Range (VNTR), Figure 7-1.

The VNTR was divided into two areas: the Eastern Maneuver Area (EMA), which included Camp Garcia, was used for public works facilities to maintain vehicles, buildings, road and utilities used for military activities, and the Atlantic Fleet Weapons Training Facility (AFTWA) was comprised of the Surface Impact Area (SIA), the Live Impact Area (LIA), and the Eastern Conservation Area.[33] The VNTR was used from the early 1950's until 2003 for ground warfare and amphibious training for marine naval gunfire support training and air to ground training. Joint exercises with other NATO countries were conducted. This is of importance because it implies that foreign-manufactured ordnance may also be encountered on the island and in the bays.

Figure 7-2 shows an image of the Bahia Salinas del Sur and part of the LIA near the shoreline. The light blue areas of sea bottom are sand. The darker bottom areas are primarily sea grasses. The fringing coral tends to appear as gray, although some areas are indistinguishable from the sea grasses in this image. Military target areas on shore are noted as red dots (mostly

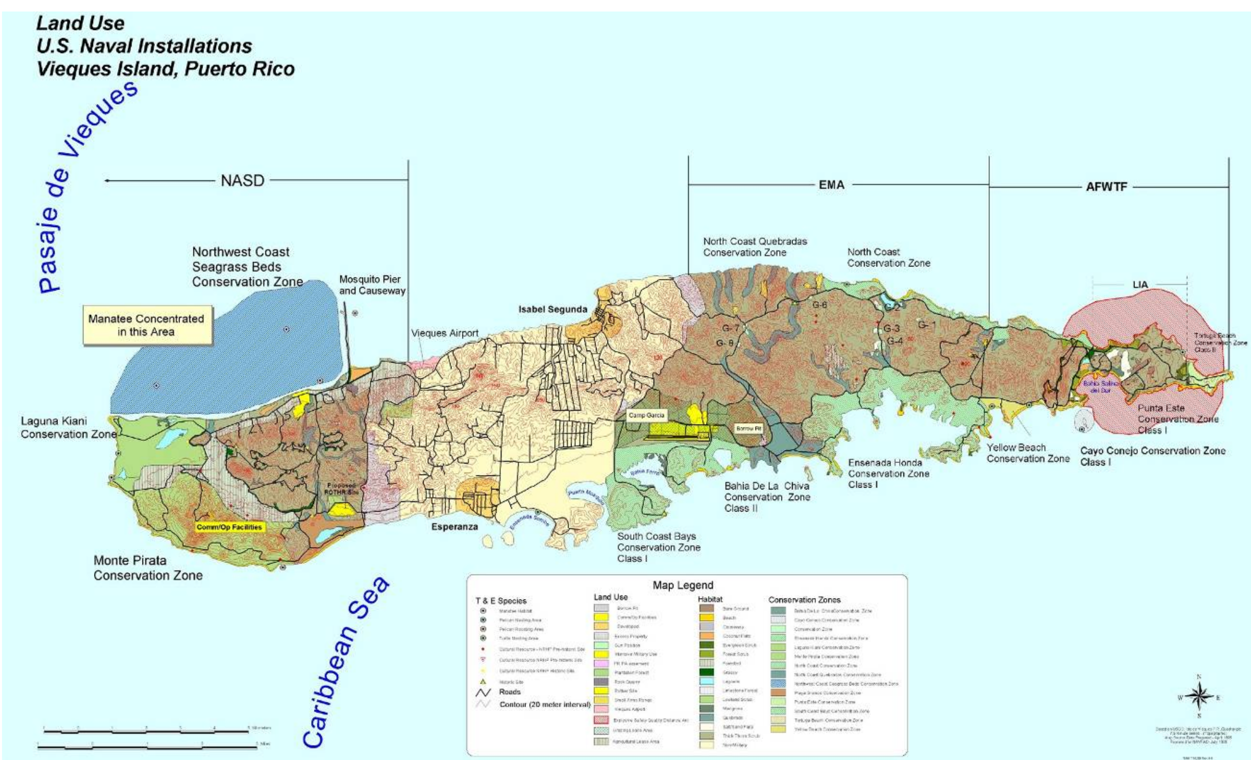

Figure 7-1. US Navy Installations Vieques, Puerto Rico (1999).

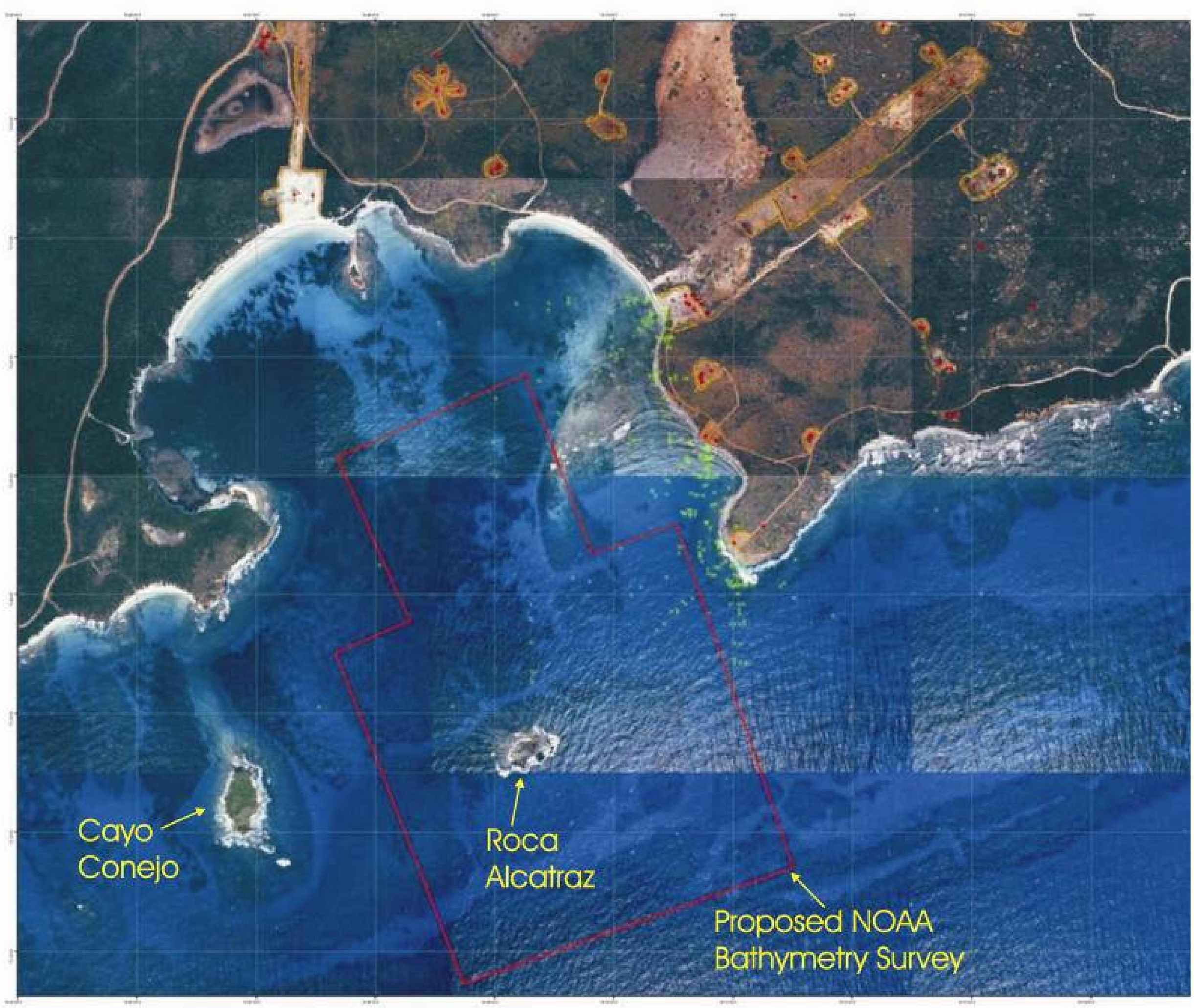

Figure 7-2. This 1999 mosaic of aerial photographs shows the Bahia Salinas del Sur with the two small islands that guard the mouth of the bay.

within scarred land areas). Green dots in the bay mark positions of known UXO previously identified by divers. The red bounded area defines the survey area mapped in a NOAA bathymetry study.[34] All roads within the LIA are unimproved (sand, dirt, or gravel).

7.1 History of Environmental Activities on Vieques

The environmental clean-up of the former VNTR on the eastern sector of Vieques Island began on January 10, 2000 under the Resource Conservation and Recovery Act (RCRA) 3008(h) Consent Order. The RCRA framework was established by Congress to address environmental problems due to hazardous waste remaining on transferring properties. On April 30, 2001, the U.S. Navy transferred approximately 4,000 acres of the former NASD to the municipality of Vieques; 3,100 acres to the U.S. Department of the Interior (DOI) Fish and Wildlife Service; and 800 acres to the Puerto Rico Conservation Trust. On May 1, 2003 the Navy transferred an additional 14,573 acres of the former VNTR on east Vieques to the U.S. Department of Interior (DOI) to be added to the Vieques National Wildlife Refuge, Figure 7-1.[32]

In 2003, the Navy conducted a munitions survey of both Bahia Corcho (Red Beach) and Bahia de la Chiva (Blue Beach). These beaches were then officially opened to the general public. They were closed again in 2004 after storms washed munitions items from offshore onto the public beaches.[35]

In 2005, the U.S. Environmental Protection Agency (EPA) placed the former VNTR and NASD areas of Vieques on the National Priorities List (NPL) thus designating these areas as "Superfund" sites. In addition to the environmental sites, there are 62 additional potential sites with munitions and explosives of concern (MEC) remaining on the former VNTR. Continuing cleanup on the site is being conducted under CERCLA guidelines following a Federal Facilities Agreement, which was developed and signed by the parties.[36]

The Navy conducted a *Preliminary Range Assessment and Phase I Extended Range Assessment* in 2005 to gather data on the quantity and types of munitions remaining on the site to prioritize sites for further study and to identify high risk sites that might require time-critical removal actions.[35] In April 2005, a Time Critical Removal Action (TCRA) began. The beaches and other high priority areas in the LIA were investigated and UXO items were identified and removed.

The MTA demonstration on Vieques Island took place as part of a site characterization and remediation project for the former VNTR site. Our MTA activities are one of several marine survey and characterization studies that have taken place offshore of the VNTR.[34] Our site characterization study was not coupled with any scheduled UXO investigation or recovery operation. UXO cleanup activities (particularly in the LIA) have been extensive over the past several years. However, to date there have been no offshore UXO recovery efforts.

All of our activities during this demonstration took place with the support and oversight of NAVFAC Atlantic Division, which is the office managing the cleanup operations on Vieques. NAVFAC Lant contributions to the MTA study were primarily "in kind." The monetary support for the MTA study was provided by ESTCP.

During a reconnaissance visit to Vieques we met with and coordinated our intended activities with John Noles and Chris Penny (NAVFAC Lant) and their on-site contractors. We additionally met with the local environmental regulators (DNER) and the Region 2 staff of the National EPA office, and with some local citizen's group representatives. Our test plan was made available in draft form to these representatives for comment. Additionally, we met with them during the MTA survey to keep them apprised of our progress and to monitor their concerns. There were a few instances of contentious interactions with local citizens groups and local municipality officials. NAVFAC Lant provided a public relations support representative from their Norfolk office to meet with these groups and to provide information relevant to our activities.

7.2 Vieques Geology

The MTA demonstration survey took place almost entirely within the Bahiá Salinas del Sur and areas just south of the mouth of the bay in open waters. The area of the bay is approximately ¾ by ½ nautical miles with water depths up to slightly more than 30 feet. The bottom of the bay consists of areas of open sand, areas covered by marine sea grasses, and coral reefs. The coral tend to be in fringing clusters around islands and along the shoreline. Areas of coral in the main part of the bay are typically associated with solid bottom structures (such as the components of the wrecked Killen (a US Navy target ship)[37] or piles of dead coral rubble (likely created by earlier ordnance detonations). The Bahiá is apparent in the aerial photograph shown in Figure 7-**3**. The entire island of Vieques had its origins in volcanic activity. There are hills, rugged terrain, and rocky outcroppings at various places on Vieques that demonstrate its volcanic origins. However, much of the island, particularly in areas close to the shore, is characterized by magnetically-benign sandy soils. The two islands protecting the mouth of the Bahiá and the hills on the west side of the bay are rocky volcanic outcroppings. The remainder of the bay and the surrounding shore areas appear to be sand. Following the MTA survey, it became apparent that the magnetic geological formations contributed only at a low level as interferences in our survey data and analyses.

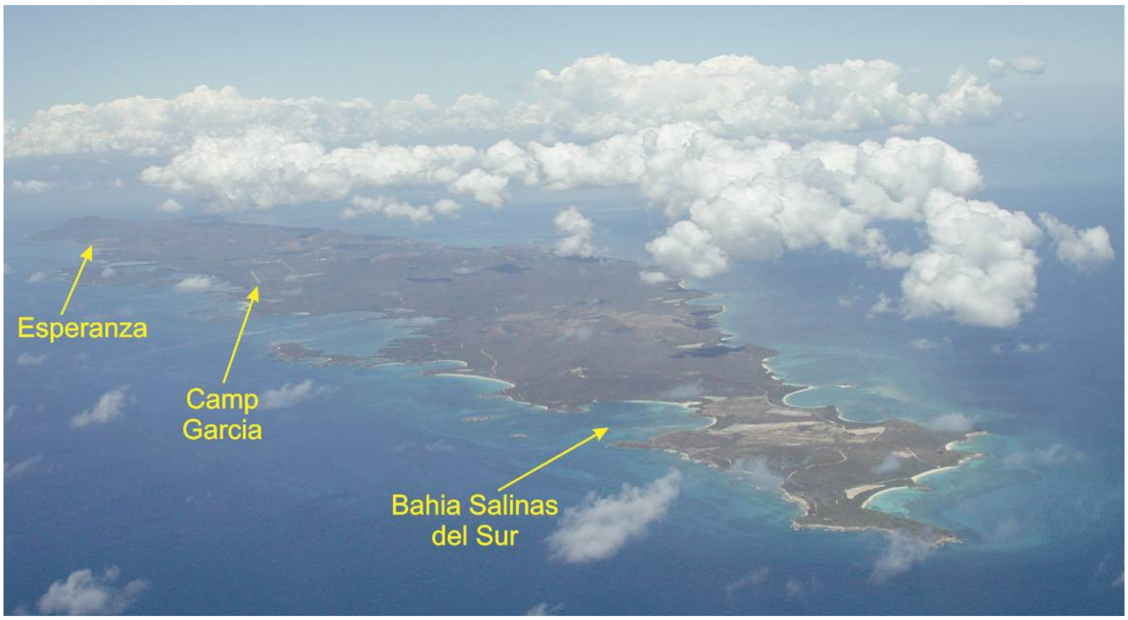

Figure 7-3. An aerial photograph of Vieques is shown with the location of the proposed survey area noted.

7-3. Logistics

We made a reconnaissance visit to Puerto Rico and Vieques in December 2006. We visited DOD officials at Camp Garcia and NAVFAC Lant and UXO contractor officials on Vieques and toured both municipal areas on the western half of the island and the support logistics available in the DoD-controlled areas. Additionally, we rode a small charter boat to circumnavigate the island, tour the potential survey areas, the ferry and private docks and the boat launching facilities. There were no boat launching facilities within 10 miles of the LIA and the only suitable boat docking facilities were either in Esperanza or at Mosquito Pier (the ferry landing on the north side of the island). Each of these facilities is more than 12 miles from the Bahia Salinas del Sur. We furthermore determined that there were no suitable vessels that could be chartered or rented on the Island of Vieques to support our survey.

The only suitable facilities (motels and restaurants) to support our field survey were either in Esperanza or near the airport/ferry dock. Either of these areas is only about 12 miles by road from the Bahiá Salinas del Sur. Unfortunately, we could not make satisfactory arrangements with the Navy security offices at Camp Garcia that would allow us to come and go without checking through the security office twice a day and waiting for escorts to accompany us to and from the beach. The security office and escorts were available only during limited parts of the day. We did use the overland access to the Bahiá a couple of times in emergencies, but it invariably required one and a half hours to complete the 8 miles from the security gate to the beach.

The only viable alternative was a daily over-water commute between Esperanza and the Bahiá. On good days with calm seas and a reasonably fast vessel this could be accomplished in slightly under an hour. This approach required that we outfit the MTA survey vessel at the municipal park in Esperanza, ferry it through open waters (towing the platform) and moor it for the entire survey period in the relatively sheltered Bahiá. The Esperanza boat launch ramp is shown in **Figure 7-4**. Overnight mooring in the Bahiá required that we maintain a 24 hour security presence on the MTA vessel and that we prepare moorings for the vessel and the platform in the Bahiá.

Figure 7-4. This image shows the launch ramp in Esperanza. The water was too shallow for Coral Queen access, which required us to launch the platform and tow it to the Queen with the skiff.

Navigation charts note mooring restrictions in the Bahiá Salinas del Sur. We requested a waiver to this restriction (from the Navy) to allow us to place temporary moorings for the survey vessel during the demonstration. This was denied, however NAVFAC, Lant agreed to have their local contractor install moorings that we could use. They installed three light anchors with buoys that we could use to moor the MTA tow vessel and the sensor platform overnight. The mooring anchors for the survey vessel failed the second day that the vessel was on site, resulting in the loss of all of our TV equipment on the survey platform. Subsequently, we bought two much larger anchors to replace the light anchors that were first installed. These proved to be successful as moorings.

While we were on the reconnaissance visit in December 2006, we visited several marinas and charter boat operators in Fajardo on the main island. We limited our search in Puerto Rico to the east coast of the island (primarily Fajardo) because this is a large city on the eastern end of the island, which has large marinas and commercial boating operations; it is also the primary ferry departure point for Vieques and Culebra. We determined that our best option in Fajardo was a dive boat charter operator, Sea Ventures. They had offices and operations at three different cities on the island. They were also recommended by the NOAA group who had just completed their sonar bathymetry studies in Vieques. Based upon our reconnaissance visit, we decided that all three survey and support vessels would be chartered in Puerto Rico, most likely from Sea Ventures in Fajardo.

7.4 MTA Equipment Transportation

Once it was determined that all the survey and support vessels would be chartered in Fajardo, we consolidated the remaining MTA equipment onto the boat trailer with the survey platform, a group of 4 ft packing crates designed for moving with a fork lift, the tow cable crate, and a group of larger items that were not suitable for crating. The latter items were secured to the trailer deck. The best option for transport for the equipment was to ship it all on a flatbed trailer (45 ft) with one of the shipping companies that provided shipping to Puerto Rico. The shipping company towed the trailer to Melbourne, FL where it was loaded onto a multilevel sea-going barge that was towed to San Juan, PR. These large barges are used to ship a whole range of commodities back and forth between the US and Puerto Rico. In San Juan, after the equipment had cleared customs, a tractor was used to transport it to Fajardo. We also rented a 14 ft box truck in San Juan to transport and secure our equipment for the duration of the operation.

In Fajardo, the equipment was unloaded from the shipping trailer into the box truck, where it was used to support the build out of the charter tow vessel, the Coral Queen, Figure 7-5. All three survey support vessels were driven across the straight to the Esperanza dock on the south shore of Vieques (see below). The box truck and the boat trailer (with the sensor platform) were transported from Fajardo to Mosquito Pier on the north shore of Vieques by the cargo ferry that runs several times a day back and forth between these two points. The ferry does not travel between Vieques and Culebra, so the equipment had to be transferred from Vieques to Fajardo and then loaded onto another ferry for the trip back across the straight to Culebra.

Figure 7-5. The transport trailer with the MTA equipment is shown being unloaded in Fajardo, after it was driven overland from San Juan.

7-5 Outfitting the Vessels

All three vessels to support the Vieques and Culebra surveys were chartered from Sea Ventures in Fajardo, PR. The charter company provided all crew (captains and mates) to support the vessels for this operation. They were responsible for providing accommodations and per diem support for the crew. In addition, they provided overnight security for the vessels and all SAIC equipment and all fuel necessary to support this operation and to deliver it as needed to the survey vessels.

The primary survey vessel was a 42 ft fiberglass dive boat, the Coral Queen, see Figure 7-6. The Coral Queen was equipped to support 18 divers in exploration and pleasure dives on coral structures and wrecks. Working with Sea Ventures,[38] we spent two days outfitting the Coral Queen to support the MTA survey. All the dive support equipment was removed from the vessel. An aluminum plate was bolted down on the aft end of the deck. The tow point assembly was bolted to this plate. Forward of the plate, one inch plywood sheets were bolted to the deck.

The equipment racks and support electronics were bolted to the plywood, Figure 7-7. The tow cable support structures were mounted behind the transom on the dive platform. Several other structures were mounted to the vessel to support the survey, Figures 7-8. The power generator for the MTA equipment was lashed down on the forward deck below the bridge.

A 21 ft fiberglass runabout vessel (the Dusky) was provided as the chase boat, Figure 7-9. It also served as the commuting vessel for the trip back and forth between the fishermen's dock in Esperanza and the Coral Queen, which was moored in the Bahiá Salinas del Sur. The transit time between Esperanza and the Bahiá was typically 50-75 minutes depending on the sea conditions. There were 3 days during the survey that the seas were too rough (8-10 ft waves) to attempt the transit. There were several other days that the sea conditions made for a very rough ride. The Dusky was fine for use as a chase boat. It was too small and underpowered to serve as a commuting vessel. The outboard engines were unreliable and were hard to fix because it

Figure 7-6. The Coral Queen is shown tied up at the marina in Fajardo. In this image it is out-fitted as a recreational dive boat.

Figure 7-7. The MTA electronics racks are shown mounted on the Coral Queen. The ladder in the foreground leads up to the flying bridge.

Figure 7-8. On the left the mount for the sonar altimeter is shown attached to the port rail. On the right the pilot guidance display is shown mounted on the bridge in front of the driver.

required flying a mechanic and/or parts from the big island to Vieques.

We knew that there were significant areas of the Bahiá that were too shallow to survey with the MTA. We requested that Sea Ventures find a flat bottom fiberglass skiff for us to use for the shallow water surveys. They leased a 17 ft Carolina Skiff, which we used to support the shallow water surveys, Figure 7-10. The skiff was moved between Fajardo and Vieques (and Culebra) by towing the vessel behind the Coral Queen. We bought the lumber, plywood, foam, and hardware to build out the structures for mounting the magnetometers, the GPS antennas, and the pilot guidance and data acquisition computers in Fajardo and did the build out in Vieques. We were concerned that the structures might not survive the trip from Fajardo. The bimini was added to improve the computer visibility for the driver. Figure 7-11 shows all three vessels tied up side-by-side in the Bahiá.

Figure 7-9. This image shows the Chase Boat temporarily docked at a pier in Esperanza.

Figure 7-10. The Carolina Skiff is shown in the Bahia Salinas del Sur. During data collection, the skiff is operated by one person.

Figure 7-11. The Coral Queen, the Dusky, and the Carolina Skiff are moored together in the Bahia Salinas del Sur.

7.6 The Survey

7.6.1 Productivity The MTA survey crew was in Puerto Rico from 1 June to 30 June, 2007. During this period, we completed 4 full days of MTA survey (e.g. >5 hr of recorded survey files) and 3 half days of MTA survey (e.g. 2-4 hr of recorded survey files). During this period, we also collected 3.5 days of skiff survey data. On 23 June we completed a full day of both MTA and skiff surveys. Table 7-1 shows the summary of the MTA survey results. There were a variety of contributing factors to this relatively low survey productivity rate. These are summarized in bullet form below.

- Four Fridays were lost to ordnance demolition days on the LIA.
- Four full days (and 3 half days) were lost because of breakdowns of the chase/commuter boat, which could not be repaired because of a lack of access to a mechanic and/or parts.
- Three full days were lost because the seas were too high for the Dusky to make the transit from Esperanza to the Bahia.
- The first 8 days of June were consumed getting the equipment from San Juan to Fajardo, building out the Coral Queen, and transporting the equipment to Vieques.
- Four days were lost waiting on seas to quiet so that the Coral Queen could tow the sensor platform between the Bahia and Esperanza. This was ultimately resolved only by chartering an LCM to move the platform twice.

Table 7-1. MTA Survey Summary

Survey Day	Survey File Length (Hr)	Line km Completed
9 June	4	18.1
10 June	6.4	27.4
11 June	10.9	45.5
19 June	1.6	6.7
23 June	8.5	35.8
24 June	2.9	12.3
26 June	5.3	23
Total MTA Survey	**39.6**	**168.8**

Several factors contributed to the relatively low survey productivity level achieved in this demonstration. The most important factor was the very long logistics reach that had to be dealt with (North Carolina to Florida to San Juan to Fajardo to Vieques to Esperanza to the Bahia Salinas del Sur). Doing preparatory home work through the reconnaissance visit and working with the local companies and agencies mitigated this to an extent. However, no matter how well planned, the many steps in the logistics chain each represented a time sink.

A second contributing factor was the fact that this was the first time that we had modified a "vessel of opportunity" to support the MTA survey. This was accomplished fairly efficiently, but because it took place several thousand miles from home (and in an area with language barriers) it required a significant presence of both SAIC and Sea Ventures personnel throughout the process.

A third factor contributing to the difficult productivity challenges was the choice of the Dusky as a commuting vessel between Esperanza and the Bahia. The unreliability of this undersized vessel (combined with the absence of mechanical support and access to parts and mechanics, cost numerous days and part days of lost time.

The most important factor that could have significantly improved our productivity would have resulted if we could have successfully negotiated with the Navy, with NAVFAC, and with their contractors to allow us an unimpeded access between the Camp Garcia gate and the beach at the Bahia. Even if it required a dedicated escort for our operations, it would have likely doubled (or even tripled) our productivity if we could have traveled overland for the few minute commute to and from the site each day.

7.6.2 Survey Operations: About one-third of our survey (80 line km) was completed using the 3-magnetometer array in the flat bottomed skiff. This included all the near shore areas, areas around the small islands, and areas along the eastern shore of the bay north of the shoals. All areas with water depths of <6 ft were surveyed this way. Figure 7-12 shows a composite image of the skiff survey superimposed on the aerial image of the Bay and the near shore areas of the LIA.

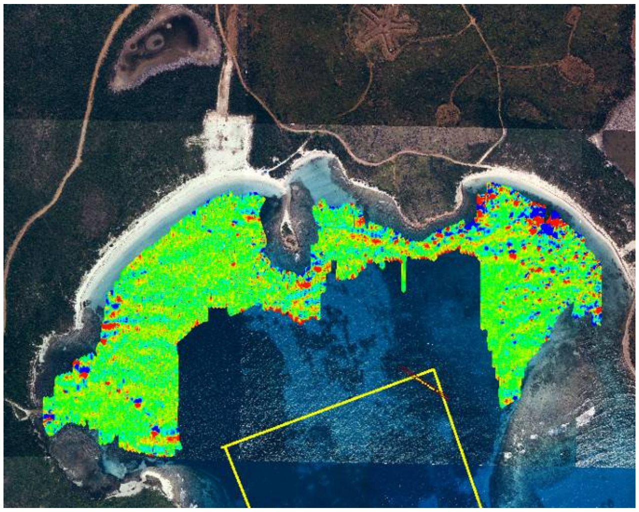

Figure 7-12. Magnetic anomaly image from the skiff survey along the north shore of the Bahia. The presentation scale is ±30 nT.

Along the western shore and along the beach in the northeast part of the bay there are remnants of former structures that have been destroyed (likely by naval or air bombardment).

Figure 7-13 shows the combination of the skiff survey and MTA survey images as a single composite magnetic anomaly image which is superimposed over the same digital orthophotograph. The dominant features in the magnetic anomaly image are the three clumps of extremely intense returns north-northeast of Roca Alcatraz. Each of these signals is from parts of the wreckage of the former target ship the USS Killen, which was sunk by naval gunfire during a training exercise.

7.6.3 Data Analysis and Results: All of the magnetic anomalies in the skiff and MTA survey data that were judged to potentially be ordnance were analyzed using the MTADS Data Analysis System to determine their locations, sizes, and burial depths. The results were organized into target tables to support possible future intrusive investigations or recoveries. The skiff survey target table contains 71 entries; the MTA table reports the results for 532 anomalies.

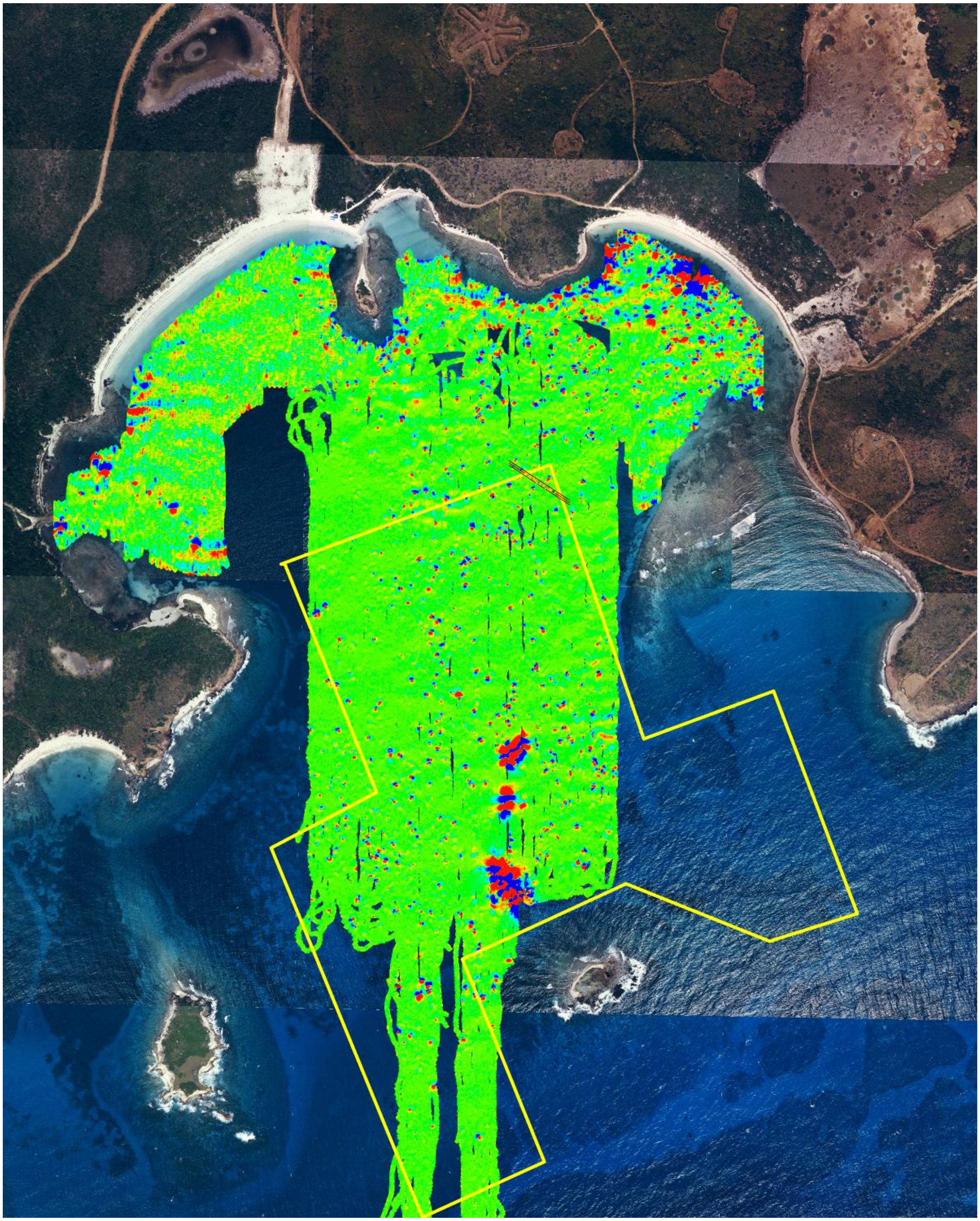

Figure 7-13. This is a magnetic anomaly image of both the skiff and MTA surveys overlaid on an orthophotograph.

8.0 Culebra

The Army Corps of Engineers (Huntsville) requested that we carry out an MTA survey of selected marine areas off the island of Culebra in conjunction with our MTA survey on Vieques. Specifically, we were requested to conduct a series of transect surveys of various bays on the southwest side of Culebra and on all sides of the much smaller island Cayo de Louis Peña. The suggested transects are shown in black overlaid on NOAA Marine Chart 25655 in Figure 8-1.

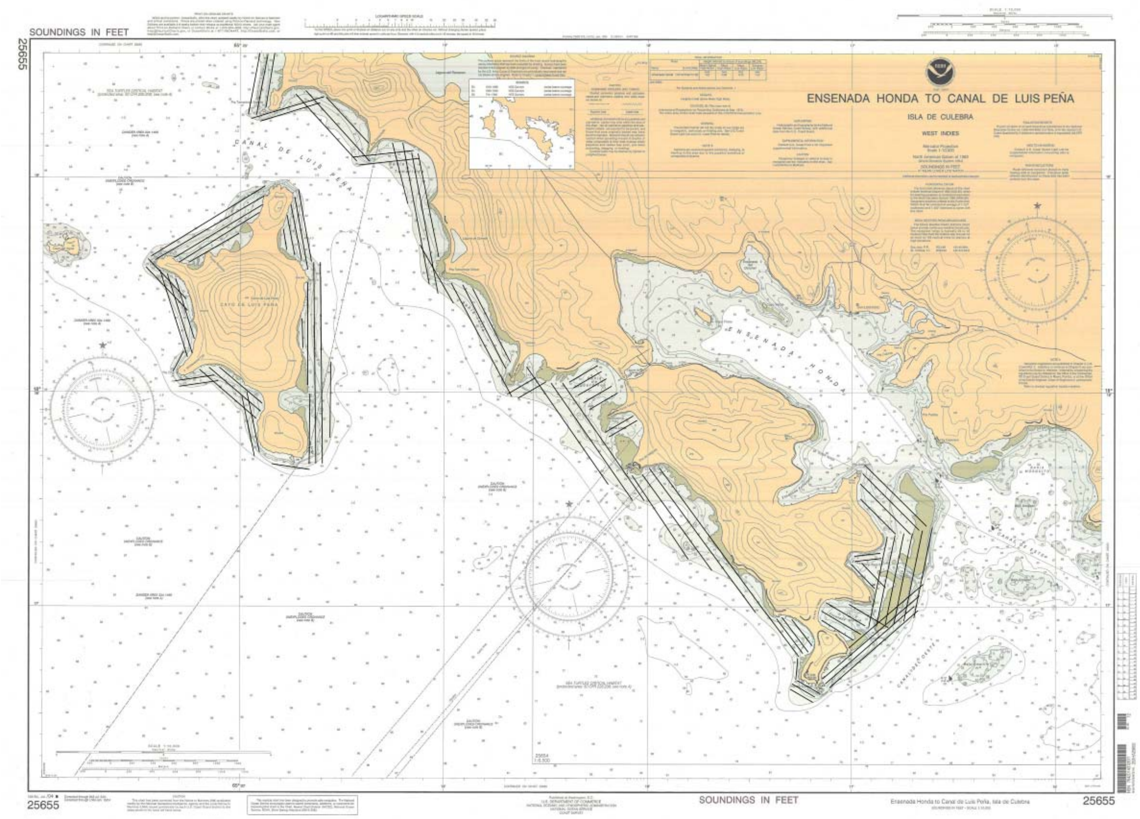

Figure 8-1. Suggested MTA survey transects are shown superimposed on the NOAA Marine Chart 25655.

8.1 Background Information

During June 2007, the areas involving the suggested transects shown in Figure 8-**1** were inspected from a boat by SAIC in conjunction with Mr. Andrew Schwartz of the U.S. Army Engineering and Support Center, Huntsville and several regulatory agency representatives from the Commonwealth of Puerto Rico, the National Oceanic and Atmospheric Administration, the Puerto Rican Department of Natural Resources, and the U.S. Fish and Wildlife Service. Certain areas were pointed out that support ongoing farming of endangered coral species. Other areas were suggested by the regulators to be particularly sensitive because of native populations of endangered coral in the extensive fringing reef systems associated with some of the bays with planned survey transects.

The transects suggested in Figure 8-1 were incorporated into a GIS system and overlaid on an electronic version of NOAA map 25655 as shown**.** The transects were regularized, made more parallel, adjusted for a more consistent separation and divided into two groups. The first group of transects were in water depths of 2-10 m, appropriate for MTA survey. The remaining transects were in water depths of 1-2.5 m and were intended to be surveyed from a flat bottom skiff using sensors deployed in the bottom of the boat.

Ultimately many of the initially planned transects shown in Figure 8-1 were not surveyed because of concerns of the various environmental groups. All transects that were planned for survey using the flat bottom skiff were deleted from the survey plan. The potential danger for damage to the fringing coral in the very shallow water could not be resolved to the satisfaction of the regulators in the available time before beginning our demonstration.

Figure 8-2. The Coral Queen is towing the sensor platform away from the Culebra public Ferry Dock.

There are dozens of moorings in the Bahia de Sardinas and constant boat traffic through the area because this is the location of the public Ferry Dock, Figure 8-2. It was also considered likely that there were many other abandoned moorings in the bay; therefore it was decided not to survey this bay. The two very small bays immediately adjacent to Bahia de Sardinas were too shallow to conveniently survey using the MTA; coral structures choked off the entrance to each bay. The bays east and north of Soldado Point were also deemed to be too shallow and too encircled by coral to be appropriate for survey using the MTA. In general, the shoreline around Culebra tends to be more rugged than that around Vieques. There are many more areas where rocky ridges appear to extend out into the sea. Following the Culebra surveys, it became apparent that there area many areas in the bays surrounding Culebra that have very high geologically-based magnetic signatures.

8.2 Logistics

Following completion of the MTA survey in Vieques at the end of June 2007, the MTA equipment was demobilized and transported to the Puerto del Rey Marina in Fajardo. The Sea Ventures support vessels were also returned to this marina (their home port) where minor repairs were undertaken. On 9 July, the three MTA support vessels were ferried from Fajardo to the Culebra Ferry docking area in the Bahia de Sardinas and stationed at public moorings in the Bahia. These same moorings were used for overnight stationing of the MTA equipment throughout the Culebra demonstration.

On 10 July the MTA equipment was moved from Fajardo to Culebra using the Public Cargo Ferry. The sensor platform was transported on a boat trailer. The remainder of the MTA equipment was transported (and stored) in a 14 ft box truck. The survey platform was reassembled at the dock. Because there was no accessible boat launch facility in this area, a backhoe was rented to launch the survey platform directly from the Ferry Dock, which was about 2 m above the water. This operation is shown in Figure 8-3. The Coral Queen was tied up at the

Figure 8-3. Because there was no boat launch facility, the MTA sensor platform is being launched from the Ferry Dock using a backhoe.

Figure 8-4. The MTA sensor platform is mated with the Coral Queen and hot tested before leaving the Ferry Dock.

dock and the sensor platform was mated with the vessel, Figure 8-4. All electrical and electronic equipment was tested before leaving the dock to begin surveying.

The Army Corps of Engineers established a new GPS control point to support this demonstration. It was high on a hill above Bahia Tarja and had near line-of-sight communication with the MTA vessel in most of the survey areas, see Figure 8-5. In the bay directly on the west side of Cayo de Louis Peña where the Cerro de Louis Peña lies directly between the base station and the bay, RTK communication with the base station was unavailable. This bay was not surveyed.

Figure 8-5. The base station was set up on a new GPS control point high above Bahia Tarja. The Fajardo passenger ferry is shown in the foreground, the island of Vieques is in the distance on the horizon.

8.3 MTA Surveys

8.3.1 Transect Surveys: During the first two days of MTA survey work the transect surveys shown in Figure 8-6 were completed. The survey transects are shown in red as "Course-Over-Ground" plots superimposed on the NOAA Marine Map. Several recorded transits into and out of the Bahia de Sardinas are not shown in the figure. Because surveying was not done with the skiff and because numerous transects were censored from the original survey plan, the survey transects shown in Figure 8-6 were completed relatively quickly. Figure 8-7 shows a more detailed picture of the transect survey, in this case for the Bahia Tarja. The Bahia Tarja is typical of bays surrounding Culebra (even the ones with beaches). The shorelines tend to be rocky and the bays have very little shallow area. The NOAA chart shows that essentially all the bays on

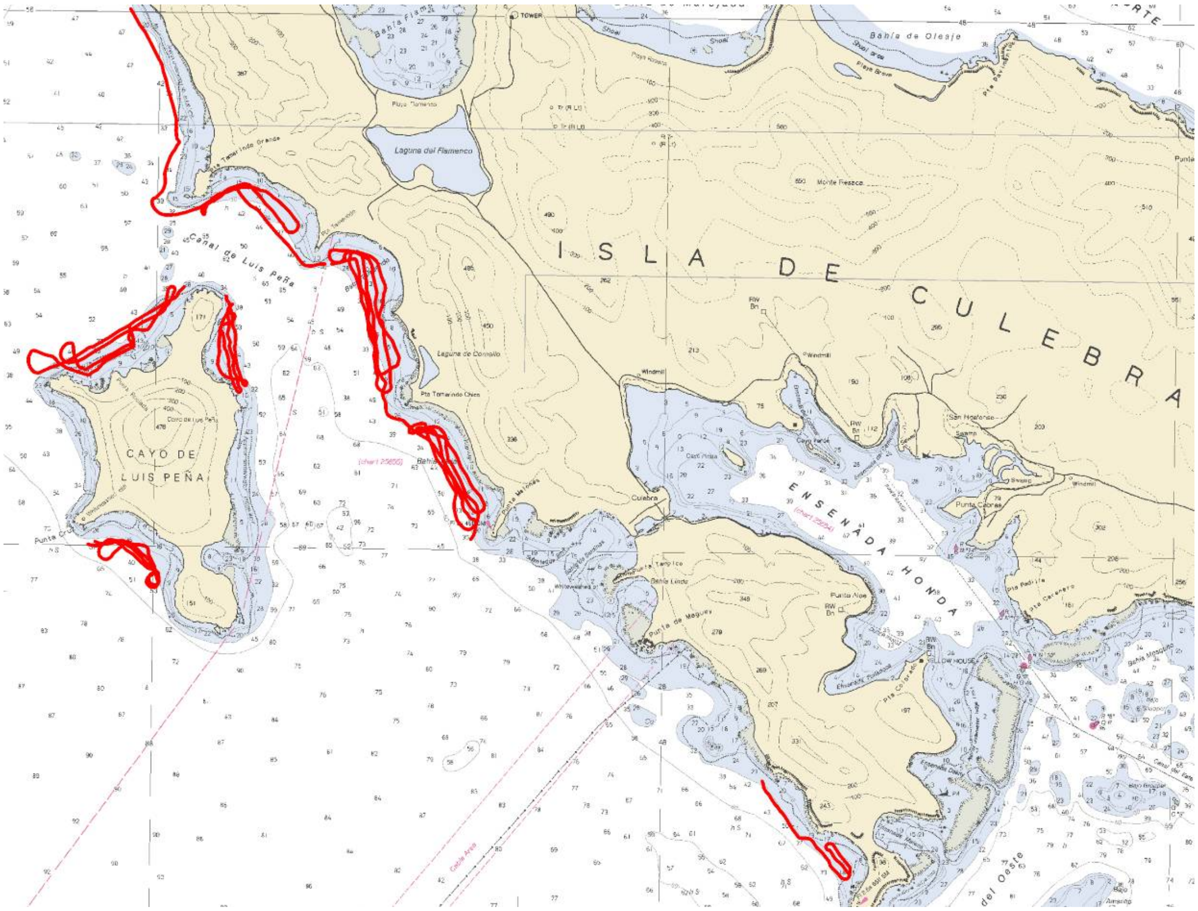

Figure 8-6. The Transect Surveys are shown in red as "course-over-ground" plots superimposed on NOAA chart 25655.

the southwest coast of Culebra and those around Cayo de Louis Peña become deep very close to the shoreline. The transition from blue to white in the marine chart is at 30 ft depths.

8.3.2 Blanket Coverage Surveys: Because the transect surveys were completed quickly, it was decided to conduct a more extensive continuous or blanket survey coverage of certain areas deemed to be of interest to the Corps site representative.

Survey grids were set up in the Bahia Tamarindo and the Bahia Tamarindo Chico on a 4 m spacing. In addition, a more extensive survey was conducted in the Soldado Point area to more comprehensively cover the calibration targets, which had been installed a year earlier by the Corps. These areas are shown as magnetic anomaly images superimposed on the

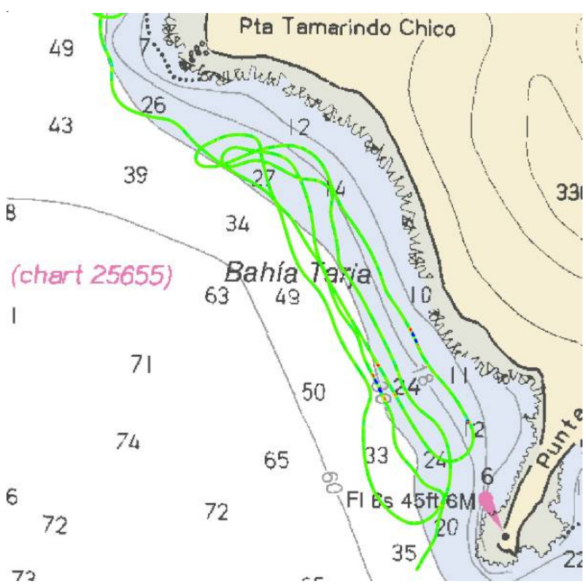

Figure 8-7. The measured magnetometry signal is plotted over the NOAA chart for the Bahia Tarja transect survey.

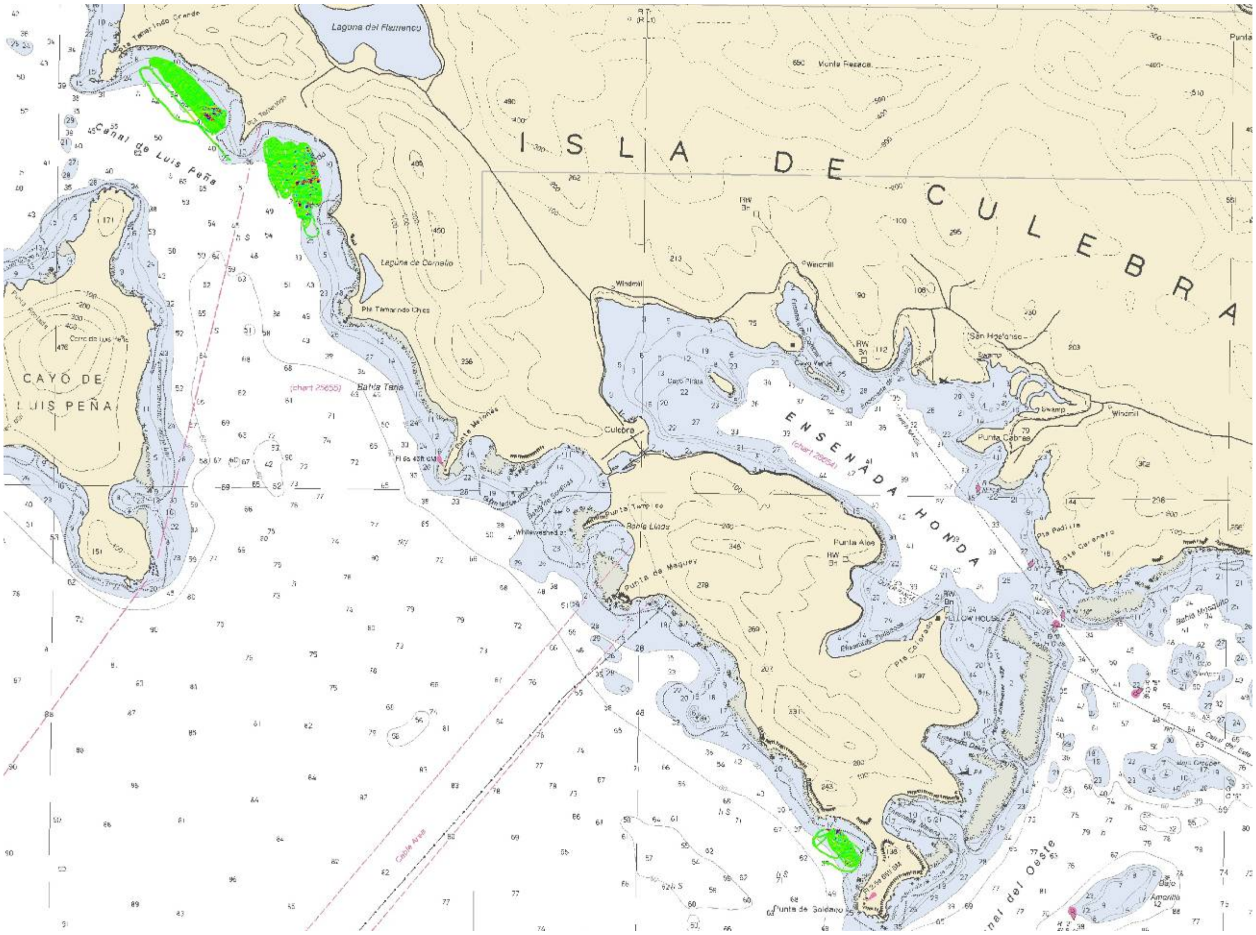

Figure 8-8. The extended survey areas are shown as magnetic mapped data file overlaid on the NOAA marine chart.

NOAA marine chart in Figure 8-8.

Figure 8-9 shows a part of the Bahia Tamarindo comprehensive survey. Almost the entire area is dominated by strong geological returns. Note the relatively course scale used in the presentation in Figure 8-9. Fifty anomalies were chosen for analysis. More than 35 of them are clearly geological in origin. To gain a better differentiation of the potentially metallic targets one could either (1) lower the magnetometer array as close to the bottom as possible (to improve the signal-to-noise of the shallow metallic targets), (2) conduct a survey with and EM array, or (3) deploy a magnetometer array in a gradiometer configuration. The latter approach would also improve the differentiation between deep geological returns and shallower metallic objects. Option (1) runs the risk of damaging coral on the bottom. Options (2) and (3) improve discrimination, but at the loss of absolute detection sensitivity.

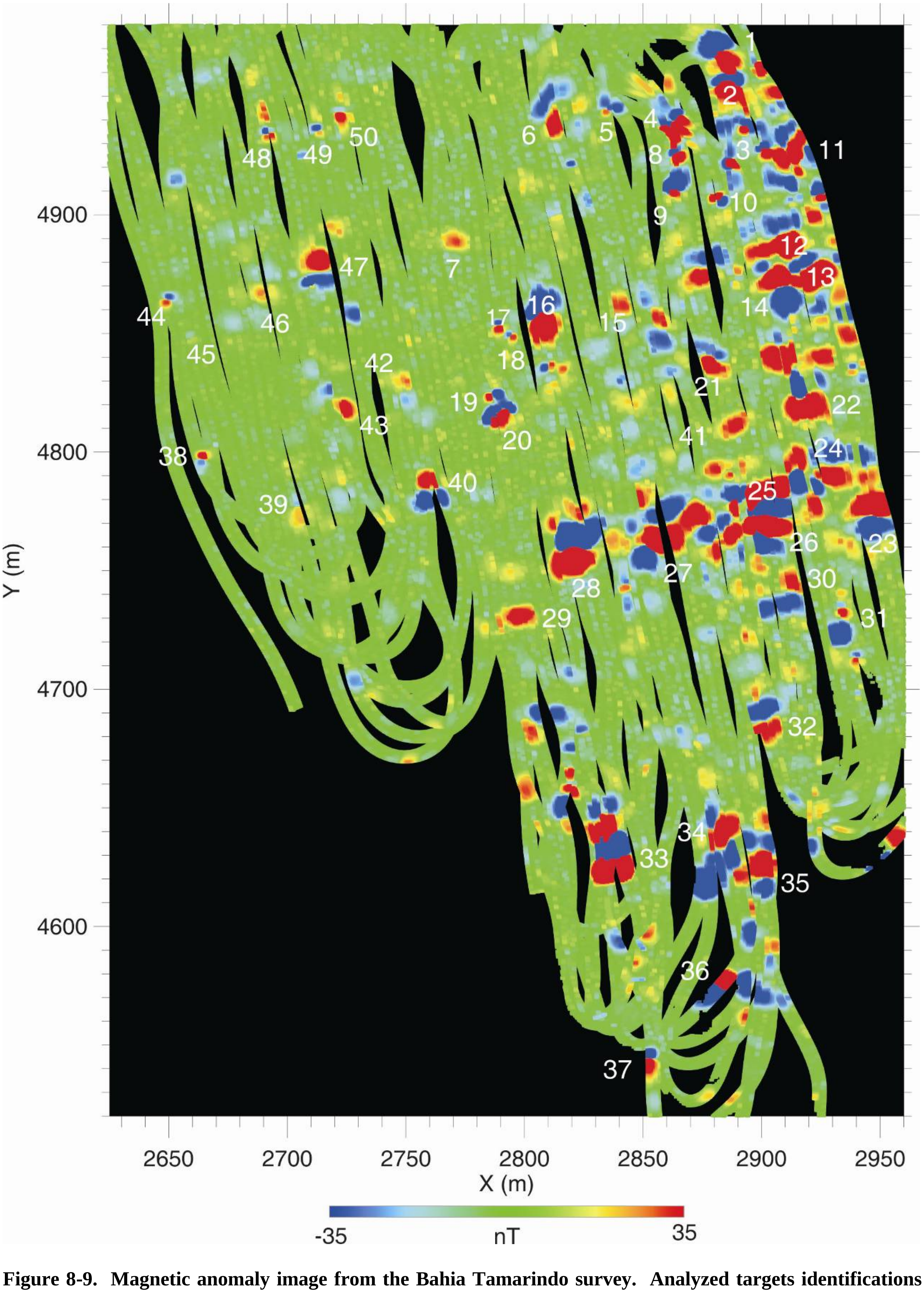

Figure 8-9. Magnetic anomaly image from the Bahia Tamarindo survey. Analyzed targets identifications are shown on the image.

9.0 Blossom Point

9.1 Test Site History

The Adelphi Laboratory Research Center – Blossom Point Field Site is located on Cedar Point Neck, a peninsula that extends into the Potomac River. The peninsula is bounded on the west side by Nanjemoy Creek and on the south and east by the Potomac River. The area to create this site was land rented/leased from the Catholic Church. When the facility was established in 1943, the mission of the site was to support testing of experimental fuzes and fuze components to support WWII operations. There are fourteen ranges associated with the site, which were used to fire projectiles, mortars and rockets over the shoreline into the Potomac River and Nanjemoy Creek. These ranges were active between 1943 and 1982.[5] There have been brief periods of inactivity during peacetime intervals. An "initial assessment" of all of the land and marine range areas was conducted in 1976. This assessment indicated that the cost of cleanup would exceed the actual property value; therefore the Army purchased the land outright. The site was re-activated in 1978 and was absorbed during the formation of the Army Research Lab (ARL).

This MTA demonstration is being conducted in cooperation with the ESTCP Unexploded Ordnance (UXO) Innovative Technology Transfer Program. It is part of a larger overall evaluation of the Blossom Point facility current and former ranges being carried out under the U.S. Army Military Munitions Response Program (MMRP). An SI has been completed[5] and an EE/CA study is currently underway which involves both the onshore and offshore ranges.[6] The objective of the MTA demonstration at the Blossom Point Research Facility is to characterize the former offshore ranges associated with the facility, particularly those lying in the Potomac River. Several ranges on the Test Facility are still active on land; however all of the water ranges have been inactive for several years.

There are fourteen ranges at this site that have range fans that extend into the water. The overlapping Water Range Fans encompass of 5,413 acres within the Potomac River and Nanjemoy Creek. These ranges were used for experimental testing of mortars, rockets, and projectiles between 1942 and 1983. The area is open water owned by the State of Maryland and is presently used for a variety of recreational purposes, including crabbing, fishing, and boating. Both the Potomac River and Nanjemoy Creek are tidal at Blossom Point. The tidal swings are modest (less than or on the order of 1 foot. Significant erosion problems along the shoreline and changes in the river bottom are primarily associated with local storms and cyclical spring flooding.

9.2 Site Conditions

Figure 9-1 shows a map based upon an aerial photograph of the Test Facility and the range fans that extend into the Potomac River and Nanjemoy Creek. Superimposed on this image is the proposed MTA transect survey (36 transects spaced at 125 m separation) that encompasses all the range fans in the Potomac. The river is dredged occasionally to maintain a 30 ft navigation channel. The measured water depths in the river include very abrupt depth changes, which have resulted from previous dredging of the channel and deposition of dredge

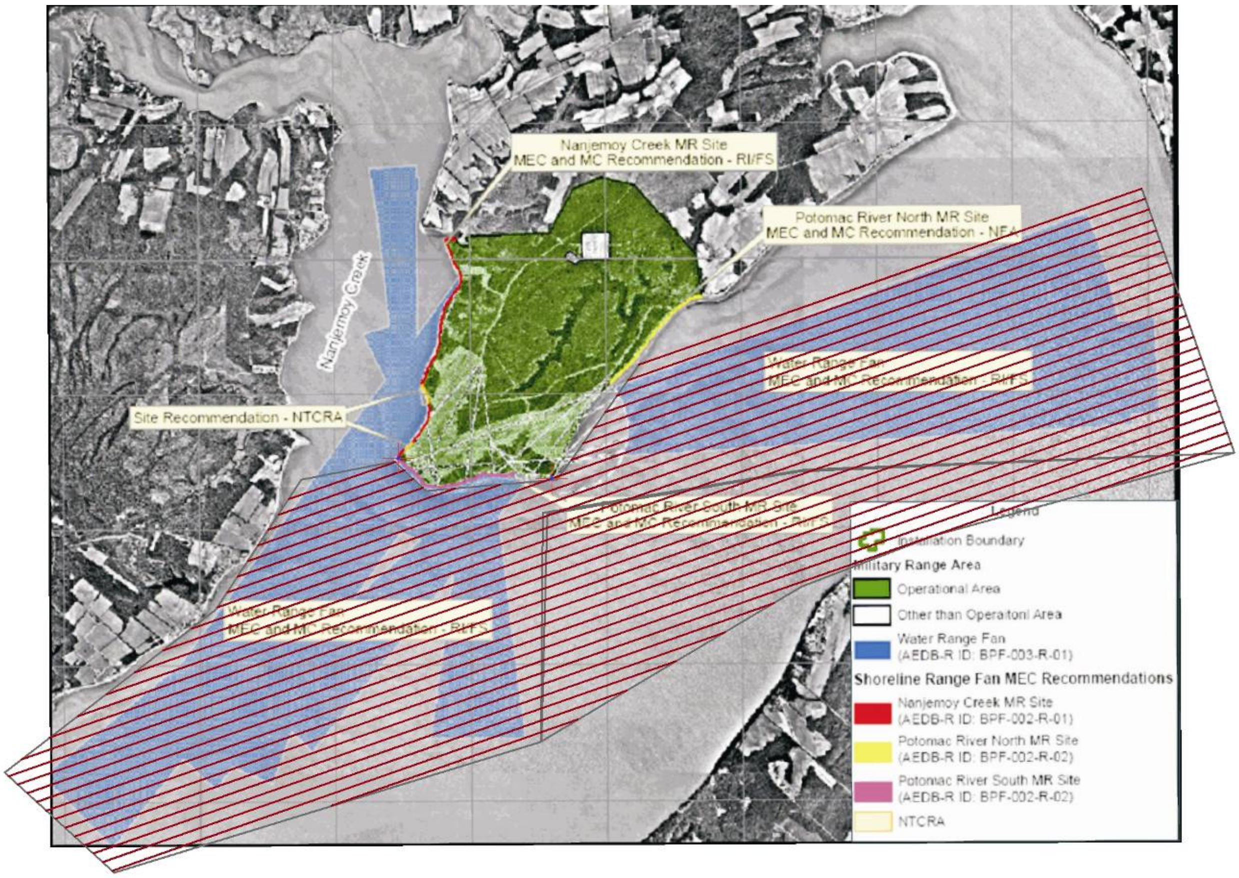

Figure 9-1. Survey Area in the Potomac River showing the survey transects as red lines. The transect separation is 125 meters.

spoils. Some of the water depths in the channel are up to ~100 ft. Water depths adjacent to the channel vary widely and may abruptly change by up to 20 ft where submerged dredge spoils have previously been deposited. Marine charts do not accurately map water depths outside the channel. These conditions required us to buy and install an additional sonar system for the boat driver to monitor these depth changes and to try to adjust the platform depth to avoid bottom collisions during survey were to either pull the boat into neutral and allow the platform to rise to the surface, or to abruptly turn right of left to avoid the piles of dredge spoils.

Except after widespread storms far upstream, the overall Potomac water depths in the summer and fall are at a minimum because of low rainfall activity. Water currents in the river are extremely complex; they vary with position relative to the channel, the depth below the surface, and the period of the tidal cycle. Currents in some places and at some water depths often flow upstream, depending on the tide. We observed surface down stream currents of up to 4 or 5 knots near the channel near bends in the river and during outgoing tide.

The bottom sediments vary from extremely soft muck that may be several ft deep, to soft or hard sand, and deeper parts of the river also include areas with hard packed surfaces. Over the past few years invasive sea grass (hydrilla) has begun to dominate many areas of the river. Because of low water visibility, the hydrilla tends to be concentrated in shallower areas. The prevalence of the vegetation also varies with the time of the year. During our operations, we did not encounter any marine vegetation in the survey areas.

Many commercial crab fishermen work all the Potomac River areas, except the channel where they are forbidden to operate. This survey took place near the end of the crab season, but there were still thousands of crab pots in the survey area, Figure 9-2. In the transect survey areas we just drove around them, in the blanket survey area they created small missed areas. In data analysis we learned to identify fully intact crab traps; however, pieces and parts of disintegrating traps were mistaken for possible ordnance.

9.3 Logistics

To transport the equipment, we rented a 14 ft box truck and a large SUV. The equipment in Cary, NC was packed out on Friday 12 October, see Table 9-1. The equipment was driven to the Goose Bay Marina (Blossom Point, MD)[40] on 15 October. We rented 3 adjacent slips in the Marina, two for the pontoon boat and the platform, and one for the chase boat, which we rented locally. The system was assembled and launched on 16 October and surveying began on 17 October following with the installation of the Calibration Line. Goose Bay Marina is about 1.5 mi from the east end of the transect lines shown in Figure 9-1.

Figure 9-2. Floats from crab pots dominated the entire survey area except in the river channel.

9.4 The Survey

Between 17 and 29 October, 2007 all of the originally scheduled transects were surveyed using the MTA. With the preliminary MTA transect data, PNNL, using their site planning tools came up with a list of 9 north-south transects near the east end of the survey area and 7 northeast-southwest transects directly off the tip of Blossom Point that they suggested should be surveyed. On 29 and 30 October these transects were surveyed with the MTA. Using the preliminary MTA transect data, the Program Office defined a Blanket Survey (100% coverage) area that they wanted to be surveyed with the MTA. This blanked coverage area is ~1565 m long**,** bounded on the north and south by Transects 9 and 11. This (32.4 ha, 80.0 acre) area was surveyed on 31 October and 1 November. The skiff surveys of the shallow water transects were completed by 30 October. The survey results are summarized in Figure 9-3. In this figure, both the originally planned transects and the additional transects suggested by PNNL are shown. The boundaries of the blanket coverage area are shown as a black box. Target picks in this area are not shown because at this scale they would completely merge into each other.

Data processing and target analysis took place concurrently with the data acquisition. By the end of the survey the Program Office was provided with the complete target reports and suggested lists of targets for reacquisition and investigation. UXO dive teams reacquired and investigated 112 targets, including 59 from the MTA transect survey, 27 from the skiff survey, and 26 from the MTA blanket survey area. The results and comparisons with the analyst's predictions are described in the survey report.[17]

The diver investigation results are summarized below in Table 9-2. Among the ordnance-related targets, no large projectiles, rockets, or GP bombs were discovered. It appears likely that the majority of ordnance fired onto the ranges were mortars, small rockets, and projectiles used to test fuzes.

Table 9-2. Summary of Diver Investigations

Target Descriptions from Diver Investigations	Number of Targets
Ordnance, Ordnance Components, and Frag	46
Metallic Scrap (Not MEC Related	34
Crab Pots and Parts of Crab Pots	21
No Finds and Too Deep to Touch	11

Table 9-1. Blossom Point Survey Log

Date	Operation	Action
Fri 12 Oct. 2007	Packout	Rent truck and SUV, Pack Equipment
Mon 15 Oct.	Mobilization	Travel to Goose Bay Marina Discover Defective Actuator Tour Site in Pontoon Boat
Tue 16 Oct		Install Calibration Line, Repair Actuator Assemble and Launch Platform
Wed 17 Oct	Survey	Repair DAQ Computer Survey Cal Line, Survey Two Transects
Thu 18 Oct		Survey Cal Line, Survey 7 Transects
Fir 19 Oct		Survey Cal Line, Survey 1 Transect Rain Stopped Survey
Sat 20 Oct		Survey Cal Line, Survey 3 Transects Crashed Platform, Return to Marina for Repair
Sun 21 Oct		Survey Many West End Short Transect Lines
Mon 22 Oct		Full Survey Day Have Completed 23 Full and Partial Transects Chris Returns to Goose Bay With Skiff
Tue 23 Oct		Build Out Skiff Analyze Targets for 8 Transects
Wed 24 Oct		Survey 5 Short Lines Rain Terminated Survey by 10:00 Analyze Targets
Thu 25 Oct		Continue Skiff Buildout Process Data, Analyze Targets
Fri 26 Oct		Show and Tell for Sponsors & Regulators
Sat 27 Oct		Idle
Sun 28 Oct	Survey	Survey 1 Transect Weather Forced MTA Back to Marina
Mon 29 Oct		Skiff Survey Starts Complete All MTA E-W Short Lines Complete All MTA East End N-S Lines
Tue 30 Oct		Skiff Survey Continues MTA Survey of All Transects Complete MTA Survey of East PNNL Lines MTA Survey of 4 West PNNL Lines
Wed 31 Oct		Set Up Blanket Survey MTA Completed 30 Blanket Survey Lines
Thu 1 Nov		Completed MTA Blanket Survey Pull Boats from Water Data Analysis & Target Lists To Program Office
Fri 2 Nov	Demobilization	Packout
Sat 3 Nov		Return to Cary
Sun 4 Nov		Idle
Mon 5 Nov		Unpack, Return Rental Vehicles
Tue 6 Nov		Return Equipment to Inventory

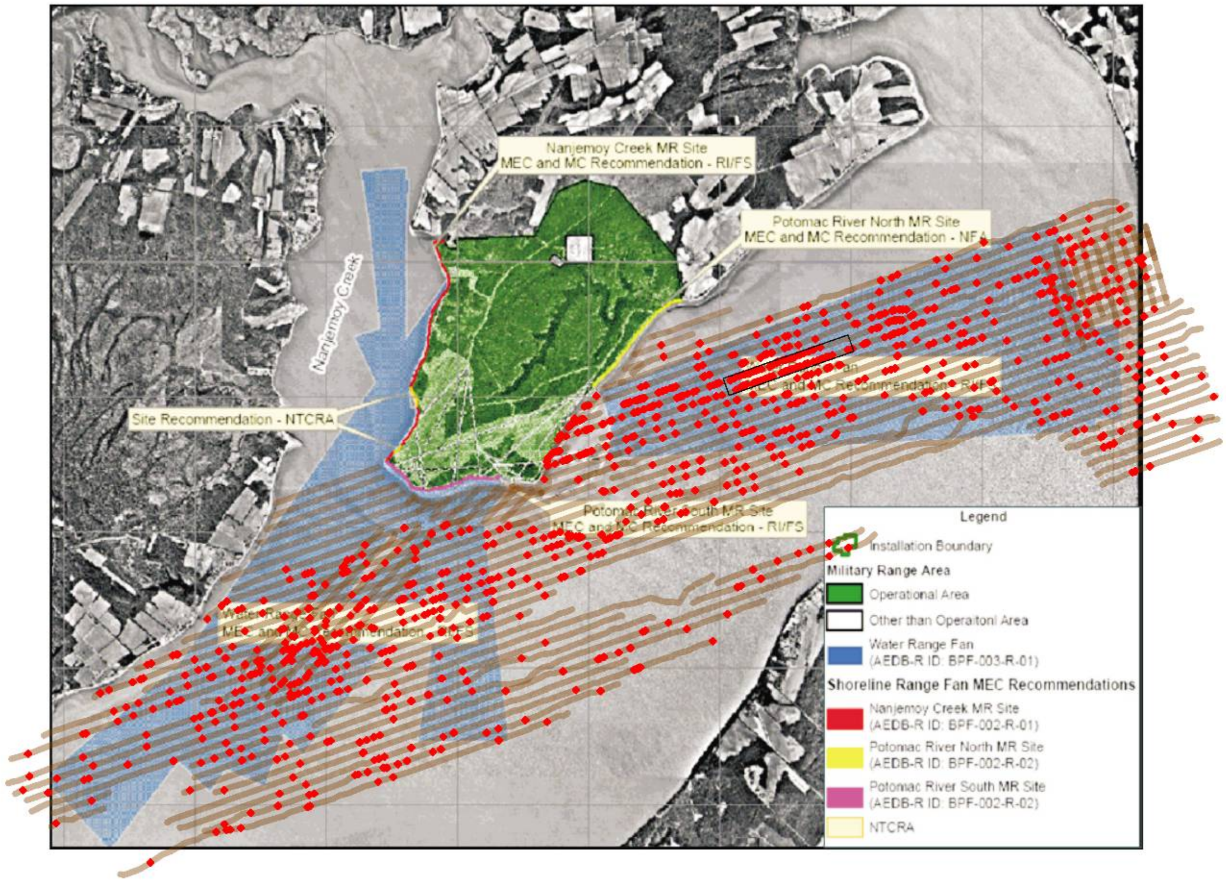

Figure 9-3. This image shows the skiff and the MTA survey transects. The targets specified by the automatic target picker are shown as red diamonds. The black box defines the approximate boundaries of the blanket coverage area. Target picks in the blanket coverage area are not shown.

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