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Coastal and Hydraulics Laboratory

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Engineer Research and Development Center

Toussaint River, Ohio, Ordnance Migration Study

Timothy Welp, Michael Tubman, Adam Hamm, and Kevin Redman

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ABSTRACT: In support of the U.S. Army Engineer District, Buffalo, the U.S. Army Engineer Research and Development Center conducted a 2-year study of the movement of Simulated Ordnance (SO) deployed in Lake Erie near the mouth of the Toussaint River. The Toussaint River is adjacent to the former Erie Army Depot, a formerly used defense site (FUDS) that contains approximately 3 miles of lake front. The objective of this study was to detertmine if ordnance that might be located in areas adjacent to the navigation channel could be transported into the channel and subsequently be encountered by future dredging operations.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U.S. statute)	1.609344	kilometers
square feet	0.09290304	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms

Preface

The field study and analyses described in this report were performed by the U.S. Army Engineer Research and Development Center's (ERDC) Coastal and Hydraulics Laboratory (CHL) and the U.S. Army Engineer District, Buffalo. A field study was conducted in Lake Erie near the mouth of the Toussaint River. The Toussaint river is adjacent to the former Erie Army Depot, a Formerly Used Defense Site (FUDS). The study objective was to determine if ordnance that might be located in areas adjacent to the navigation channel could be transported into the channel and subsequently be encountered by future dredging operations. The study and subsequent analyses were conducted in support of the Department of Defense's Defense Environmental Restoration Program. The Buffalo District is the host district for this site, and is responsible for maintaining a Federal navigation channel in the Toussaint River. U.S. Army Engineering and Support Center (CEHNC), Huntsville, AL, and U.S. Army Engineer District, Louisville, provided safety oversight and anomaly avoidance during the field operations. Evans Hamilton Inc (EHI), contracted by ERDC, constructed the simulated ordnance (SO), and, in conjunction with ERDC, CEHNC, the Buffalo District and the Louisville District personnel, deployed, surveyed, and recovered the SO, and assisted in the data analyses and report preparation. The U.S. Navy Explosive Ordnance Disposal Mobile Unit Two, Detachment Crane, Indiana, through coordination by Mr. Lance Brown of the Explosives Ordnance Disposal Technology Division, Naval Sea Systems Command, provided diver support to recover the SO at the end of the study. Logistical assistance was provided by the Camp Perry Training Site. Access through the Davis Besse Nuclear Plant property was coordinated through the Security Office, while access through ARES property was coordinated by the ARES Management Administration.

ERDC participants were Mr. Timothy Welp in the field study, Messrs. Welp and Michael Tubman in the analysis, both of CHL. Buffalo District participants were Ms. Sophie Baj, and Messrs. Michael Mohr, Thomas Bender, and Adam Hamm. CEHNC participants included Messrs. Wayne Galloway, Frederick Allan, Gregory Bayuga, Roland Belew, Preston Kiss, Jerry Kresge, and James Walker. LRL participants were Messrs. Wandell Carlton and Kevin Jasper. Contract personnel from Evans Hamilton, Inc., included Messrs. Kevin Redman, Kenneth Fitzgerald, Richard Petters, Ollie St. Clair, and Jeffery Cox. Explosive Ordnance Disposal Mobile Unit Two, Detachment Crane particiapants included CWO2 Kenneth Robinson, AOCM Mark Gerwig, BMC Danny Johnson, and PH1 Rich Steele. Camp Perry Training Site personnel included Mr. Marty Mortus, scheduler for Range and Training Areas and Maj Barbara Clemmens, Commander. Davis Besse Security Team members were Messrs. Dale Miller,

Arian Bless, Russell Merkins, and Daniel Reese. ARES management administrator was Ms. Ann Yamrick.

Contract support was provided by Mr. Sam Corson and Ms. Wendy Thompson of CHL, and Ms. Sandy Staggs of the U.S. Army Engineer District, Vicksburg. Ms. Jacqueline Greer of CHL, Ms. Patricia Bertsch of Great Lakes and Ohio River Division, and Ms. Hilda Cooper of Headquarters provided management support during the project.

Work was performed under the ERDC general administrative supervision of Mr. Thomas Richardson, Director, CHL, and Dr. William, D. Martin, Deputy Director, CHL.

Director of ERDC during publication of this report was Dr. James Houston. Colonel James Rowan, EN, was Commander and Executive Director.

1 Introduction

In support of the U.S. Army Engineer District, Buffalo, the U.S. Army Engineer Research and Development Center (ERDC), and its contractor, Evans Hamilton Inc. (EHI), conducted a 2-year study of the movement of simulated ordnance (SO) deployed in Lake Erie near the mouth of the Toussaint River. The Toussaint River is located approximately 35 miles east of Toledo, OH (Figure 1), and is adjacent to the northwestern end of the former Erie Army Depot, a Formerly Used Defense Site (FUDS) that contains approximately 3 miles of lakefront. The former Erie Army Depot was acquired by the U.S. Department of Defense in 1918 to provide additional military facilities for acceptance of artillery for the U.S. Army. The base was excessed in 1966 by the General Services Administration. Installation missions included proof firing programs, storage and issue activities for ordnance activities, support for propulsion and internal guidance systems, and inert ammunition (U.S. Army Engineer District, Detroit, 1993).

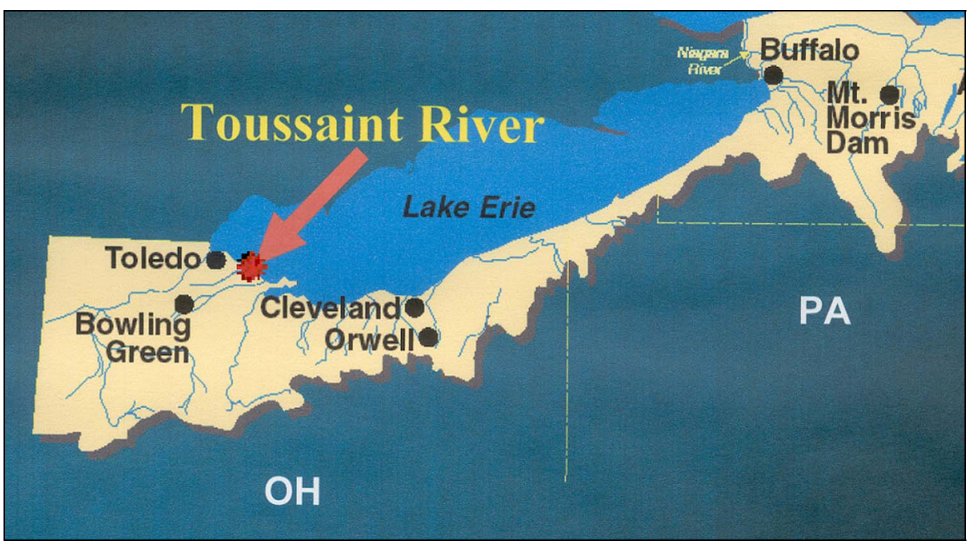


Figure 1. Location of Toussaint River

Erie Army Depot impact areas were located in, near and offshore of this stretch of shoreline. A federally maintained navigation channel from the mouth of the Toussaint River out into Lake Erie has been dredged since 1991. During the first USACE dredging operation in 1991, a 106-mm artillery projectile was found jammed in the dredge's cutterhead, and the dredging operations were immediately halted approximately 9 percent short of completion. Subsequent dredging operations in 1995 and 1999 have been conducted using extensive and costly safety measures. The objective of this study was to determine if ordnance that might be located in areas adjacent to the navigation channel could be transported into the channel and subsequently be encountered by future dredging operations.

The use of both metric and English systems of measurement in this report is predicated on the common use of both systems in engineering practice and the exclusive use of English units by the navigation industry. In the USACE, water depths are typically expressed in feet and accuracy standards are expressed in feet. Distances are measured in either meters or feet; however, accuracy standards are expressed in meters. Engineering project coordinates are normally in English units (feet). Construction measurement quantities are normally measured in linear feet, square feet, or cubic yards; however some recent construction plans and specifications are using metric units of measure. Ordnance dimensions are predominantly measured in metric, as are parameters relating to ice. Due to the variety of mixed measurements, equivalent conversions have been provided in some instances to promote USACE translation from English units to metric.

Background

Under Section 107 of the 1960 River and Harbor Act (as amended), the Toussaint River was established as a project approved for navigation improvements, and in July 1991 a contract was awarded for dredging at the mouth of the river. The contract called for establishing a 150 ft-wide, approximately 2,100 ft-long Federal navigation channel from the mouth of the Toussaint River out into Lake Erie using conventional dredging methods with no ordnance-related safety measures. A cutterhead dredge with a 406 mm (16-in.) diam discharge pipeline was used for the project. The project was nearly completed (47,000 yd^3 of the required 55,000 yd^3 of material to be dredged had been removed), when dredging operations were halted due to safety concerns. The piece of ordnance is believed to be a 106-mm projectile of the type fired during testing and proof-firing at the Erie Army Depot. As a result, the total contract cost was $\$6.22/yd^3$ instead of the approximately $\$5.06/yd^3$ that would have been the case if no ordnance had been encountered.

As a result of this initial encounter with ordnance while conducting dredging operations at the mouth of the Toussaint River, extensive safety precautions were taken during subsequent dredging operations conducted in 1995 and 1999. The 1995 operation is described by Welp et al. (1997). In that operation, an 80-ft crane was used to maintain a minimum separation distance of 52 ft between the operator and the clamshell bucket used to conduct the dredging. In addition, the operator sat behind a protective barrier. The clamshell bucket deposited the dredged material on screens placed over the dump scow hoppers that were designed to pass sediment and retain ordnance. The screens were monitored using a remote-controlled camera, and if a suspicious object was observed on the screen, dredging was halted until it could be positively identified. Thirty-seven pieces of ordnance were recovered and properly disposed of during the operation. These precautions resulted in a contract cost of $40.04/yd^3$, with 19,300 yd^3 removed. In 1999, a clamshell dredge with operator and crew protection was used to dredge the channel again, but this time no screens were used. No ordnance was observed in the barge loads, and dredged material was taken to an open-lake disposal area. The barge was equipped with a protective barrier for the operator. The total estimated cost for this project was $13.82/yd^3$ with 49,961 yd^3 removed.

Under contract to the U.S. Army Engineer Division, Huntsville, EOD Technology (EODT) cleared the 3 miles of shoreline of ordnance and explosive waste (OEW) in 1992 (EODT 1993). However, during an inspection conducted early in 1993, after the cleanup, additional ordnance was observed, suggesting that natural coastal processes may be transporting ordnance from offshore and depositing it on the beach. During September 1993, ERDC conducted a study "to assess underwater and beach ordnance distribution patterns for the Lake Erie Impact Area and the implications of these patterns in terms of past, and therefore, future influences of coastal processes" (Pope et al. 1996). The deepest depths surveyed during this study were 14 ft. Hypotheses were developed regarding the mobility and pathways of ordnance transport in the dynamic environment of this site. The study concluded that there are "tremendous quantities of ordnance" just lakeward of the beach and the nearshore sandbars, and that ordnance in the nearshore bar field are subject to onshore migration and exhibits a tendency for limited alongshore transport. Beyond a depth of about 6 ft, out to 14 ft (i.e., the study limit), "ordnance in this area is not very mobile, and does not exhibit any evidence of a net transport trend."

Williams (2001) studied the movement of actual inert unexploded ordnance (UXO) and unrestrained cylinders under wave action. These studies built on earlier ones by Davis (1999), and Davis et al. (1999), which applied to UXO movement in uniform flow. These laboratory studies found that in uniform flow, movement occurred when a flow velocity threshold was reached, but under wave action, a threshold flow velocity did not exist (i.e., UXO movement was uncorrelated with a single minimum current velocity). When waves are present, their periodicity and nonlinearity appear to be the important factors. ERDC conducted a small field study to verify these laboratory results at its Field Research Facility (FRF) in Duck, NC. Two plastic cylinders weighted to be similar to UXO were instrumented with acoustic transponders and deployed in water depths of approximately 13 and 16.5 ft. Acoustic tracking of the cylinders over a 4-month period revealed that they moved approximately 49 and 42 ft respectively, and verified that under wave action, a threshold flow velocity for movement did not exist.

Purpose

This study has been undertaken to investigate the possible movement of simulated ordnance (SO) under wave, current, and ice conditions in Lake Erie in the vicinity of the mouth of the Toussaint River. The ordnance-like objects deployed in this study primarily consisted of items that were simulations of ordnance known to have been fired at the Erie Proving Grounds. They were simulations of the following ordnance:

a. 60-mm High Explosive mortar round (60-HE M49A3)

b. 81-mm High Explosive mortar round (81-HE M56)

c. 81-mm High Explosive mortar round (81-HE M43A1)

d. 90-mm armor piercing round (90-APT)

e. 106-mm High Explosive Anti-Tank round (106-HE M344)

The SO, identified by individual tracking frequencies, were deployed in several nearshore areas in the vicinity of the Toussaint River in depths less than 6 ft. SO were deployed on both sides of the Toussaint River navigation channel where they could potentially be moved into the channel, and alongshore southeast of the Toussaint River in documented impact areas, where they could potentially be transported toward the river. These locations were chosen to provide information on movement as it related to the potential of encountering ordnance during future dredging operations. Surveys to relocate and map the SO positions were conducted over a 2-year period, during which the SO were exposed to a range of lake wave, current, water level, and ice conditions.

2 Site Background and Characterization

Erie Army Depot History

The former Erie Army Depot, Ottawa County, OH, is located along the western shore of Lake Erie (Figure 2). Camp Perry was established in 1907 by the state of Ohio for the training of the state National Guard. 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 used to proof fire (check for accuracy) thousands of pieces of artillery. 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 Erie Proving Ground. During the next 5 years, 70 percent of the mobile artillery used by the U.S. Army, or provided to Allied armies, was tested and proof-accepted at Erie Proving Ground. Between 1946 and 1951, the site reverted to a peacetime role and was renamed the Erie Army Depot. Late in 1951, the depot assumed the additional roles of antiaircraft support testing and the overhauling of surface-to-air guided missiles (support to the Korean Conflict). Additional activities included logistical support to Regular Army and National Guard antiaircraft units training at Camp Perry (U.S. Army Engineer District, Rock Island, 1993).

Test firings of Vietnam-era munitions continued into the early and mid-1960's. The Erie Army Depot was excessed by the General Services Administration in 1966 and closed in 1967. The majority of acreage encompassing the former Erie Army Depot site is no longer Federal property and is now classified as a FUDS. Approximately 5.7 km^2 (1,400 acres) of property at the former Erie Army Depot were acquired by negotiated fee, and 1 km^2 (240 acres) was long-term leased from the state of Ohio to private landowners. Former Erie Army Depot buildings are currently used by Erie Industrial Park complex.

Several impact areas in Lake Erie were established by the Erie Army Depot to test fire artillery barrels. Approximately 388 km^2 (96,000 acres) of Lake Erie, and 5.78 km^2 (1,427.75 acres) of land, are classified as formerly used target areas (Figure 2). In addition to the test firing conducted by the Erie Army Depot, these impact areas were extensively used in training missions by the Navy, Air Force, National Guard, and Army Reserves. This multiuse and 75-year history of ordnance firings is reflected by the wide range in type and caliber of ordnance recovered on or near the former impact areas. Ordnance recovered or identified on the FUDS site beaches include a broad variety of direct fire and indirect fire munitions currently or formerly maintained in the arsenals of U .S. military forces. Shells range in size from the largest World War I 240-mm and more recent 155-mm artillery rounds, to smaller World War II 45-mm armor-piercing and 1960's 60-mm mortar projectiles and modern small-caliber rifle cartridges associated with present Camp Perry activities. For a detailed description of Erie Army Depot, see Pope et al. (1996).

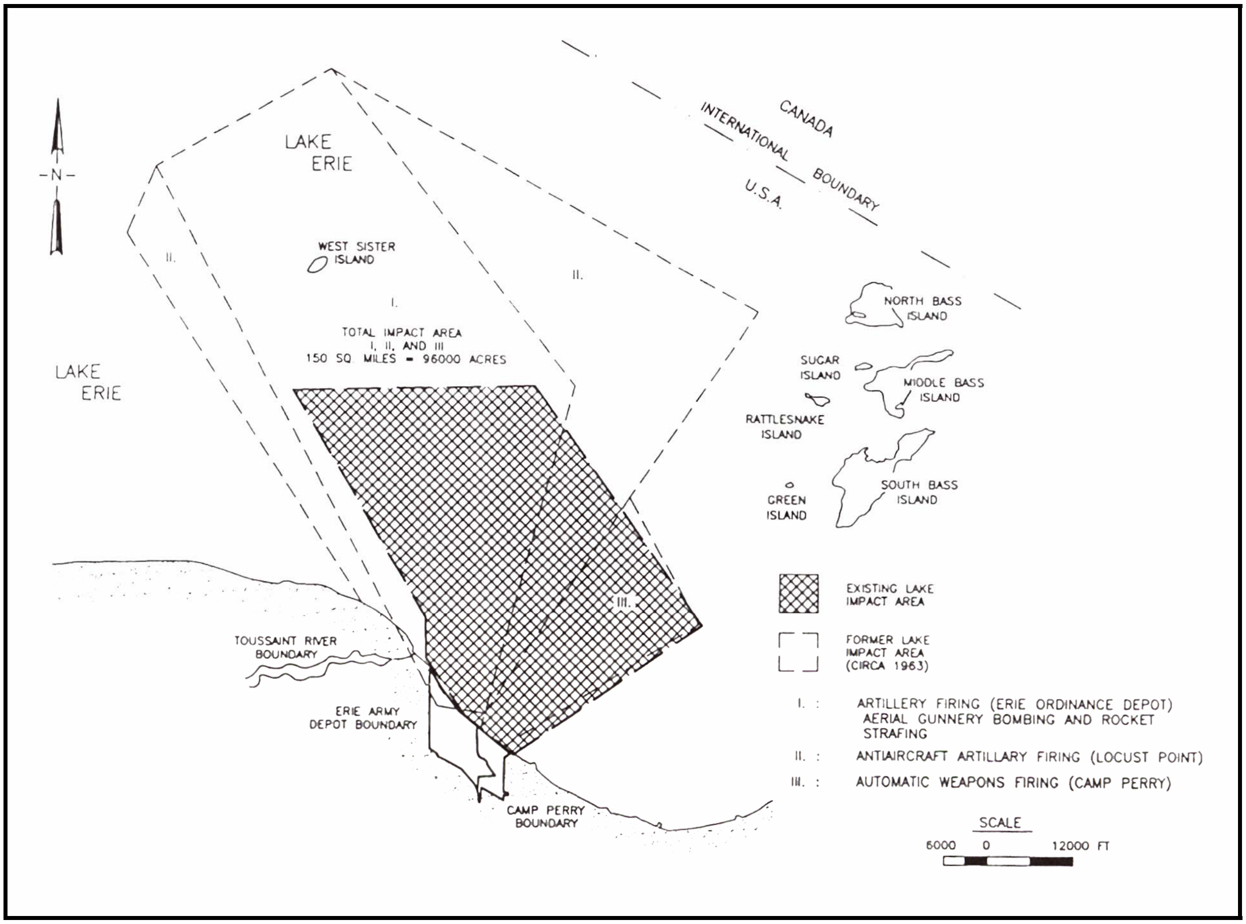


Figure 2. Erie Army Depot and Camp Perry lake impact zones

Federal Navigation Project at Toussaint River

1991 Dredging Project

The Toussaint River project was approved for navigation improvements under Section 107 of the 1960 River and Harbor Act, as amended. In May 1984, the initial appraisal was completed and during September 1990, plans and specifications were completed and the project was approved for construction.

The construction contract was awarded to Marine Construction Company (who subcontracted it to Luedtke Engineering Co.) in July 1991. Dredging commenced 29 August 1991 at the mouth of the Toussaint River (as shown on the location map in Figure 3, near Port Clinton, OH. The new works project consisted of establishing a 150-ft-wide Federal navigation channel from the mouth of the Toussaint River to Lake Erie, a reach of approximately 2,100 ft, and pumping the dredged material into a nearshore placement area. The authorized channel depth was 3.8 ft below low water datum (4.0-ft pay depth plus 1.0-ft overdepth).

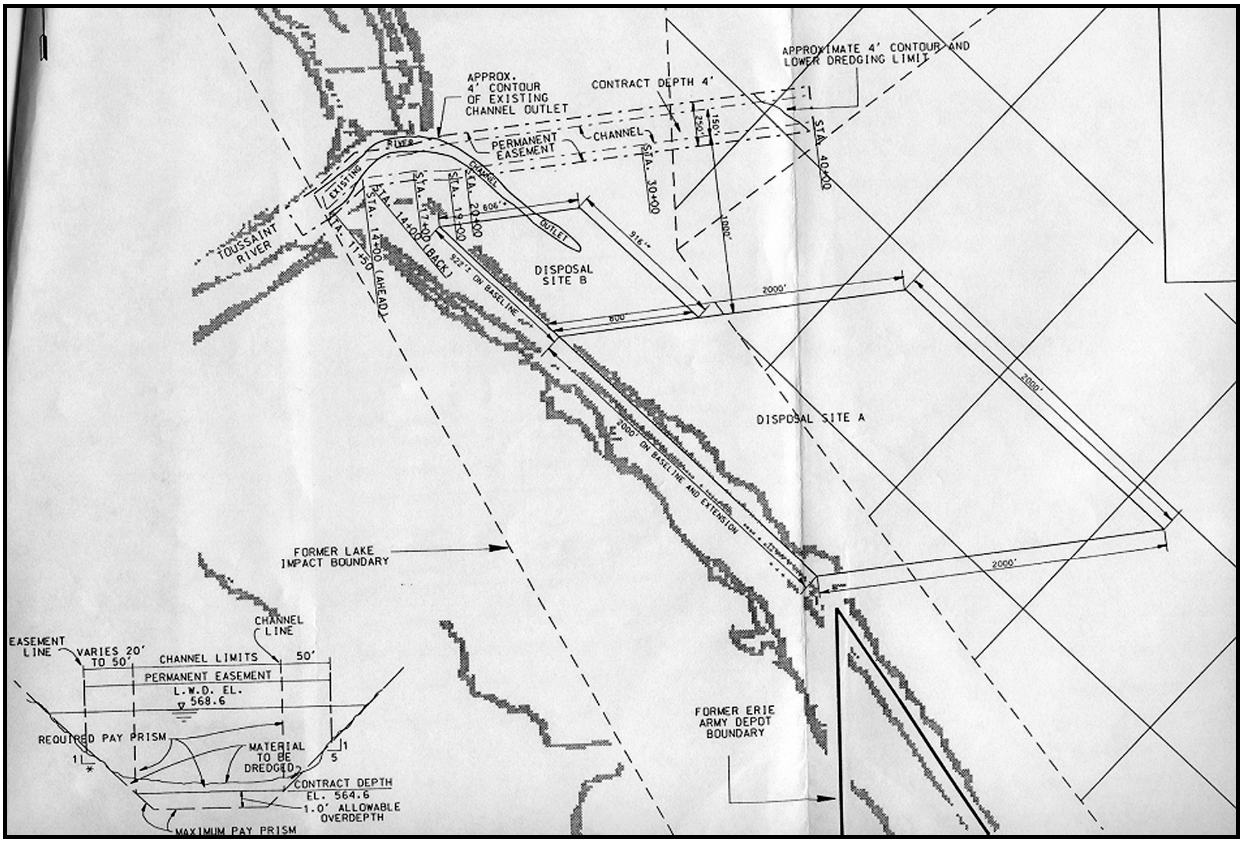


Figure 3. Authorized Toussaint River Federal navigation channel and disposal sites

The contract involved a 406-mm (16-in.) cutterhead dredge (*Lucille T*). Dredging was nearly completed (47,286yd^3 out of 55,000 yd^3) when on 25 September 1991, the cutterhead was jammed with a 106-mm projectile, and the Buffalo District immediately halted dredging operations by terminating the contract for the protection of the dredge crew. The initial (bid) contract unit price was \$3.00/yd^3. As a result of the ordnance presence (ordnance delays and impacts), the total contract cost was \$6.22/yd^3 instead of the approximately \$5.06/yd^3 that would have been the case if no ordnance had been encountered.

1995 Dredging Project

The 1995 Toussaint River dredging project consisted of a demonstration project conducted by the Bubbalo District under the auspices of the Defense Environmental Restoration Program (DERP) - Formerly Used Defense Sites (FUDS). The purpose of this demonstration project was to evaluate the operational effectiveness of a clamshell bucket dredging process, modified with additional safety precautions and engineering controls, for dredging unexploded ordnance (UXO)-contaminated channel sediment. In the context of this report, ordnance will be defined as bombs, warheads, missiles; artillery, mortar ammunition, etc.; any device that is explosive or otherwise designed to cause damage to personnel and material. UXO will be defined as items of explosive ordnance that have failed to function as designed or have been abandoned, discarded, or improperly disposed of, yet still remain capable of functioning.

An important design consideration was to safely recover UXO for proper disposal, as opposed to exclusion-type designs that depend on leaving ordnance "on the bottom." The dredging methodology selected for the demonstration consisted of removing river bottom material with a modified clamshell bucket dredge and depositing it upon separation screens placed over dump scow hoppers. These screens were designed to pass sediment and retain UXO with separation being accomplished by a combination of gravity flow and a water jet fluidization system. As dredged material was placed onto the screen surface, it was visually monitored by an explosive ordnance disposal (EOD) contractor (under contract with the Huntsville U.S. Army Engineering and Support Center) through a remote-controlled camera system to detect UXO as the sediment "sifted" through. When a suspicious object was detected dredging ceased, and the item was positively identified. If the item was determined to be an ordnance hazard, it was recovered, transported to shore, and disposed of by the EOD contractor. Once the scow was filled, the sediment and debris remaining on the screen was cleared by the EOD contractor, and the dredged material was deposited in a nearshore disposal site.

Shoreline Contractors of Lakewood, OH, was awarded the dredging contract. The contract was based on the maximum number of demonstration dredging hours that could be provided within the allocated $500,000 cost constraint. The hourly cost rate included all costs associated with anticipated weather delays, equipment repair, passage of public boaters, transporting and disposal of dredged material, and all other items necessary to meet the contract specifications.

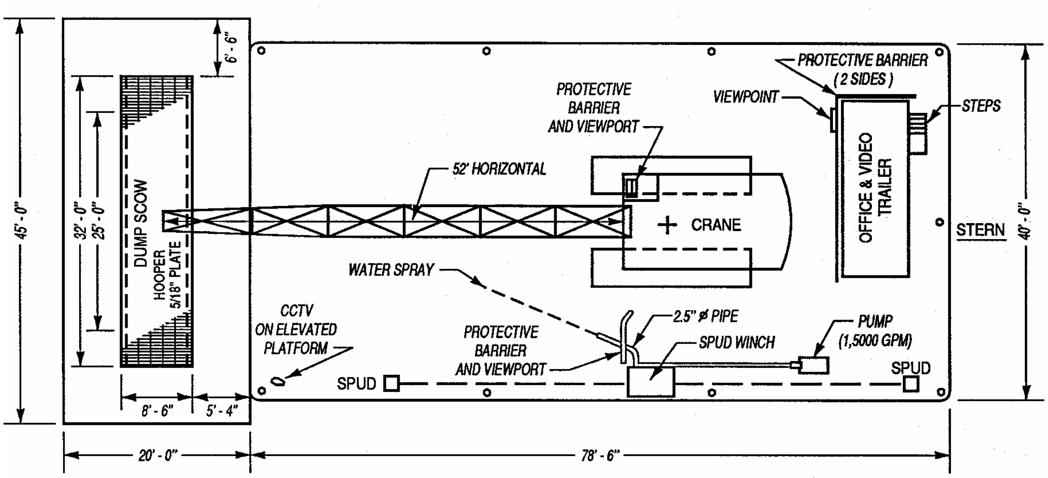
An 80 ft-boomed crane with 3 yd^3 toothed-clamshell bucket was used on a spud barge by the contractor for excavating the predominately medium-grained sand (average d_{50} of 1.2 mm). An additional 3 yd^3 bucket was held in reserve in case the first bucket was damaged by UXO detonation. Engineering controls to address health hazards due to potential UXO detonation consisted of enclosing the crane operator's booth with a 0.25-in.-thick steel plate protection barrier with a viewing window made of 2.5-in.-thick polycarbonate laminate. This viewing window provided shielding equivalent to the 0.25-in.-thick mild steel.

The 80-ft crane was required because it allowed the operator to maintain a minimum separation distance of 52 ft from the clamshell bucket (also a protective barrier). The Huntsville Engineering and Support Center designed appropriate safeguards, including the protective barrier and the separation distance, using the computer program CONWEP to analyze effects of a potential detonation (i.e., equivalent weight of TNT, peak over-pressure, fragmentation, etc.). CONWEP was developed as a supplement to the TM5-855-1 "Conventional Weapons Effects" manual and incorporates the equations and empirically based curve fits for trajectory and shell penetration analyses. This analysis was based on a 106-mm projectile, the maximum-sized UXO perceived as a threat.

The clamshell excavated material from the navigation channel and placed it onto the scow secured "alongside" as shown in Figure 4. The project used two 85-yd^3 capacity bottom-dump scows to transport dredged material to the disposal site. These scows were maneuvered by the shallow-draft workboat (in addition to the spud barge and both scows) that allowed dredging to be conducted in water depths as shallow as 4 ft.

The contract specifications required that the maximum screen opening dimensions be 0.75 in. in one direction and 5 in. in the other direction. These dimensions were based upon the design objective of retaining 20 mm projectiles. The screens used by the contractor initially consisted of coal-tar epoxy coated bar grating with 0.75-in. by 4.5-in. openings 0.75 in. deep, but these dimensions were modified as the project progressed. Soon after dredging commenced, it became obvious that, the screen's 0.75-in. by 4.5-in. openings were becoming excessively clogged (blinded off) by clamshells and rounded coarse gravel. Cleaning debris that were wedged in the grates proved to be a time consuming, labor-intensive job. As the clamshell dredge excavated deeper into the sediment, unexpected amounts of clay (brown-gray with medium high plasticity) and peat were encountered. This clay further decreased production due to the water spraying system's inability to reduce the more cohesive clumps. These increased amounts and types of debris remaining on the screen surface after the scow was full, would, in turn, increase the time required by EOD personnel to safely inspect and clear. With approval from the Huntsville Engineering and Support Center, it was decided to expand the screen opening area by cutting out every other lateral grate bar. The removal of these laterals increased the rectangular dimensions to 1.5 in. by 4.5 in. This modification dramatically increased screen throughput by allowing more clamshells and coarse gravel to pass through (less blinding), but, when encountered, the more cohesive clumps of clay and peat still remained troublesome.

A total of 37 pieces of ordnance were recovered from the separation screens and properly disposed of (resulting in 568 lb of scrap metal). From this total, 31 pieces were classified as inert ordnance, and the remaining 6 as UXO (HFA Inc. 1996). In Figure 5, a 106-mm projectile can be seen in the condition that it was recovered from the screen. Table 1 classifies the total amount of ordnance recovered during the demonstration. During the 79 workday duration of the demonstration project, 72 days of actual dredging removed 19,300 yd^3 of material from the authorized channel limits as determined by hydrographic survey. The other 7 days were spent conducting various tasks such as altering screens, repairing dredge plant, etc. An overall production rate of 26.4 yd^3/hr, or



a. Plan view of deck layout (courtesy of Shoreline Contractors, Inc.)

b. UXO dredging system

Figure 4. Dredging system configuration

264 yd^3/day, was attained by the dredge plant at a cost (including equipment fabrication) of \$25.43/yd^3. EOD personnel support and services contract incurred an additional cost of \$14.61/yd^3. The total demonstration production cost was \$40.04/yd^3.

1999 Dredging Project

The 1999 Toussaint River dredging project was conducted 2 September 1999 through 10 October 1999 by a modified clamshell dredge and scows (Figure 6), but this time the scows were not equipped with separation screens (and water spray system) and EOD personnel were not present (on a daily basis) at the

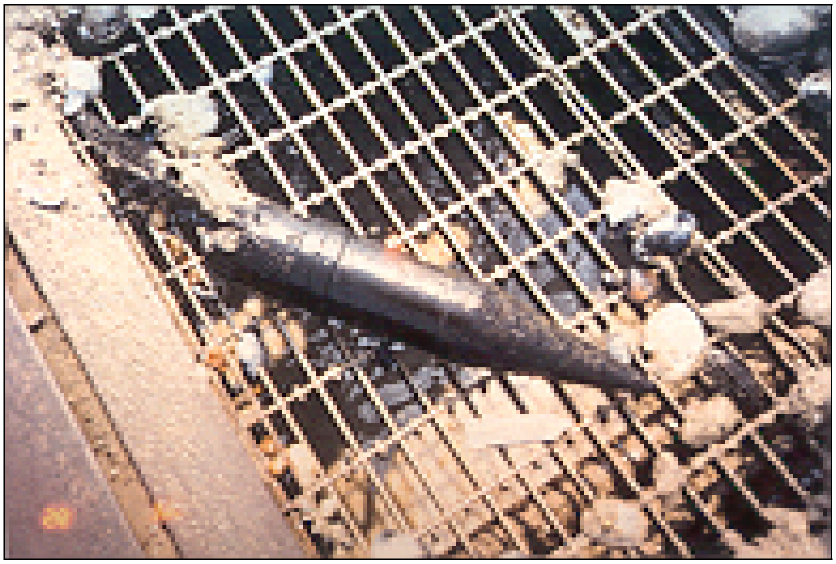


Figure 5. 106-mm projectile and clam shells on separation screen

Table 1
Total Ordnance Recovered

Ordnance Type	Quantity
UXO	
M28 3.5-in. Rocket	4
M49A2 60- mm mortar	2
Inert Ordnance	
M344 106-mm projectile	22
M52 Fuze	1
M15 Smoke Grenade	4
M489 105-mm projectile	3
M333 90- mm projectile	1

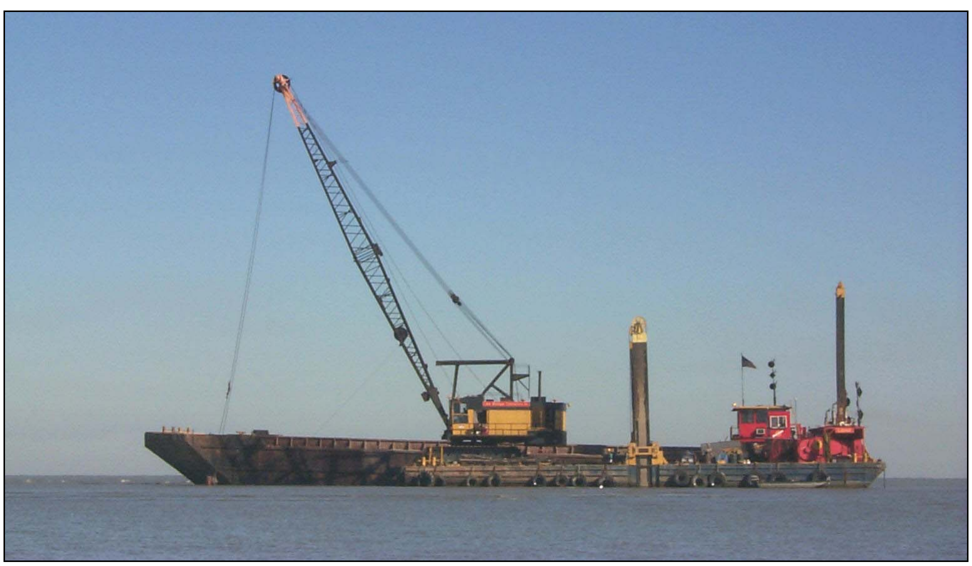


Figure 6. 1999 dredging layout

dredge site. The bid contract was awarded to Lake Michigan Contractors Inc. If ordnance was discovered any time during operations, the contractor was to stop operations in the affected area, mark the location, notify EOD personnel of the OEW hazard and area's condition, and notify the contracting officer. Then the EOD personnel (from Wright Patterson Air Force Base) were to make the appropriate arrangements for evaluation and proper disposal of each device.

The contract specifications required that the crane operator be protected by protective barriers possessing structural properties equivalent to 1.0-in.-thick steel plate protection barrier (as compared to the 0.25-in.-thick plate required in 1995)(Figure 7), as well as the crew on the spud barge (Figure 8) and the scow release operator. The scow operator was to be protected during dumping operations, from any potential exploding ordnance. The protection provided was similar to the crane operator's protection and was located at the scow release-mechanism station (Figure 9). A “Safety Zone" of 1,250 ft between the disposal scow and any other vessel was in effect during disposal operations. No personnel were allowed on the scow during transport operations, and once over the disposal area, a single workman was transported to the scow to accomplish the unloading procedure. That workman was required to be behind the protection equipment prior to opening any of the scow doors.

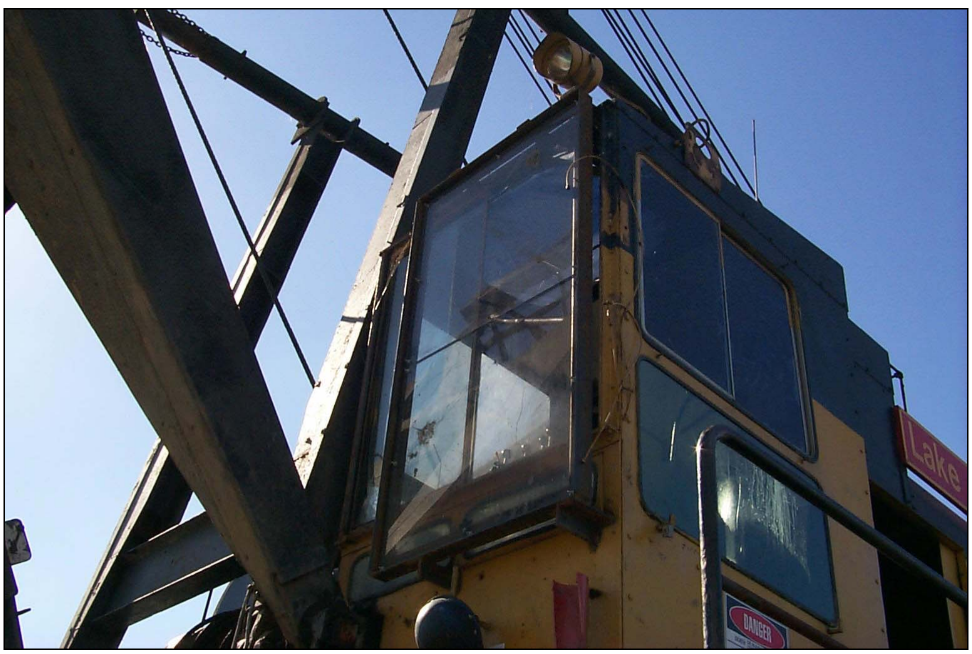


Figure 7. Crane operator's protective barrier

A minimum separation distance of 52 ft had to be maintained between the crane operator and clamshell bucket. For public safety considerations, the nearby river channel and surrounding areas was closed to marine interests within the 1,250-ft "Safety Zone" of the dredging plant and scows. Marine interests were allowed to use the river channel, within the established "Safety Zone" for a maximum of 15 min every dredging hour, and during nondredging periods. If there were no local marine interests waiting to use the channel, the contractor continued his dredging operations.

Figure 8. Crew's protective barrier (underneath life jacket)

Figure 9. Scow release operators protective barrier

All plant equipment, including dredging barges and tug and power boats, were required to be capable of navigating safely in water depths (initially) as shallow as 4 ft. Negotiations indicated that the minimum-sized scow was 1,000 yd^3 and that the clamshell bucket be at least 5 yd^3. One spare clamshell bucket was to be on site. The contractor used two 1,000 yd^3 scows with a 5-yd^3 bucket. Dredged material was transported nearly 4.5 miles to an open-lake disposal area in approximately 20 ft of water. During the entire dredging project, no ordnance was encountered in the authorized Federal channel. The total estimated cost for this project was $13.82/yd^3$ with 49,961 yd^3 removed.

Physical Geography

FUDS Beach

The now privately owned FUDS beach area along Lake Erie from the mouth of the Toussaint River to the Camp Perry boundary was evaluated for OEW and UXO in late 1991. The area surveyed was part of the former Erie Army Depot and was approximately 5 km (3 miles) long with a variable beach width ranging from no dry beach to approximately 150 m (500 ft) of dry beach. It was determined that a substantial amount of UXO may be present at the site, and an OEW interim removal should be conducted under the DERP-FUDS program. From 1 September through 9 December 1992, EODT, under contract to the Huntsville Engineering and Support Center, removed or exploded in place all the OEW which could be visually seen on, or was within 1 ft of, the beach surface from the still-water surface to 500 ft inland. A total of 5,438 OEW items, ranging from small-caliber cartridges up to and including large pieces such as 165-mm projectiles were identified and removed with 1,432 ordnance items classified as UXO (approximately 26 percent of the total ordnance items recovered). The largest populations of ordnance recovered are presented in Table 2.

Table 2
Largest Percentages of Ordnance Recovered in 1992 FUDS Beach Removal Action

General Ordnance Type	Percent Recovered
20 mm	24
60 mm	23
106 mm	15
105 mm	14

During this removal and cleanup operation, EODT maintained a detailed record of ordnance finds classified by type, condition, and location. They installed a temporary network of steel rebar to establish lanes ranging from 50 to 200 ft in width across the entire length of the FUDS beach.

From 20 May through 15 August, 2002, a time critical ordnance and explosive (OE) removal action was conducted on approximately 1.9 km (1 mile) of the FUDS beach by American Technologies Inc. (ATI), under contract to the U.S. Army Engineer District, Louisville. Twenty-nine lanes that were 200 ft wide extended lakeward from the line of the "tide debris line" as seen on the 16 November 2000 pre-proposal contractor site visit, or to the 3-ft water depth (during lowest water level occurring during the removal action), whichever results in a shorter lakeward distance" (ATI 2002). This area was cleared of surface ordnance and ordnance-related scrap. The removal action lanes were initiated from the Camp Perry boundary, and proceeded towards the Toussaint River (23 successive lanes), while the remaining six lanes were selected from beach areas closer to the Toussaint River. The type of ordnance and ordnance scrap cleared were catalogued, and the items' initial positions logged by Global Positioning System (GPS). In addition to these types of data, the compass bearing of the items' longitudinal axes were also logged. Plots showing the ordnance items' position and orientation were provided by ATI. Of the 3,193 ordnance items removed from the site, 22 were classified as UXO (0.7 percent of the total items removed). The largest populations of ordnance were 40-mm (15 percent), 60-mm (51 percent), 75-mm (7 percent), 81-mm (4 percent), 90-mm (2 percent), 105-mm (9 percent), 106-mm (4 percent), and 155-mm (1 percent).

Federal navigation channel and mouth of Toussaint River

The remaining description of the site's physical geography is summarized from Pope et al. (1996). The study area was located along the south shore of the western basin of Lake Erie. 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 the Ohio National Guard Camp Perry, and the western boundary is in the immediate vicinity of 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, and in many areas the backbeach consists of a thin boundary of scrub and woodlands. The FUDS shore has a history of rapid erosion. 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. This narrow beach is backed by a thickly vegetated marsh and an open-water channel and lagoonal complex.

Coastal processes

This section presents a general description of the study area coastal processes. See Chapter 4 of this report for more detailed information on site conditions during the study. Water levels in the study area respond to the normal annual variability of Lake Erie (annual and seasonal trends). Average annual water levels typically vary over a 0.6-m (2-ft) range, with the highest levels in the late spring/early summer (June and July) and the lowest levels in winter. Historical maximum and minimum recorded levels are approximately +1.5 m (+5 ft) to 0 m low-water datum (LWD). 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.

A wave hindcast study conducted for Lake Erie includes 32 years (1956-1987) of computed wave heights, directions, and periods for sta 2 located offshore of the study site (lat 41.73° N, long 83.08° W, with a water depth of 9 m) (30 ft) (Driver et al. 1991). This computed wave information represents wave conditions approximately 24 km (15 miles) offshore, near the Canadian border, in a location which is not sheltered by the geometry of the land or islands. However, these data show that the western basin of Lake Erie is not subject to large waves, with the annual mean wave less than 2 ft (0.6 m) and peak periods of 3.6 sec.

Generally, the highest waves occur during the winter months (November through April) with monthly means of 0.7 to 0.8 m (2.3 to 2.6 ft), while the summer months (June through September) experience monthly means of 0.5 m (1.6 ft). The stormiest months tend to be March and April, which is a period also characterized by the breakup of the ice cover. The largest significant wave computed for sta 2 is 2.6 m (8.5 ft) for a storm which occurred in April 1958 with winds out of the east (88 deg). The study area would have been somewhat sheltered from this event, and other big storms that tend to roll down the axis of the lake by the shoreline and island geometry.

The indented geometry to this shore and the presence of Catawba Island and the Bass Island complex to the east, shelter the FUDS beach from all wave directions except those from the north-northwest through the east-northeast (Figure 2). The most severe conditions are those where the winds and the waves are out of the northern sectors. In this case the shallow offshore and short-period "local " waves can result in an agitated sea state with steep shoaling waves. Under these conditions, the silty, fine lake bottom sediments will be disturbed causing the water column to become turbid. However, when the winds are from the southern (particularly the southwestern) sectors, the site is calm. Local water level may actually lower as the water surface is set up toward the northern shore of Lake Erie.

Another process important to this site is the almost 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 cover. This ice sheet usually encases the south shore, including the study area (National Oceanic and Atmospheric Administration 1983). Lake ice can both isolate the nearshore bottom and the beach from wave forces or (particularly during ice breakup) can act as a tool, increasing the damages of the waves. Ice damages to shore developments are common in the Great Lakes. However, the effect of the moving and rafting ice sheet on bottom sediments and shore erosion is a poorly understood phenomenon, particularly as it relates to sediment (and object) transport.

Potential and dominant littoral transport characteristics for the study site have important implications in terms of the beach condition and the migration of ordnance. Longshore transport indicators suggest that the quantity of material being transported is relatively small compared to more exposed sites along Lake Erie and also that the predominant transport direction is not well defined. The largest waves approach the site from the northwest through northeast directions with a fetch length of 40 km (25 miles). The predominant direction of littoral transport at the mouth of the Toussaint River through the FUDS study area to Camp Perry is from northwest toward the southeast. Based on the geometry of the shore and geomorphic indicators, the potential for transport toward the southeast should increase as you move toward the east, with less dominance at Toussaint River and more dominance at Camp Perry. The bend of the river entrance channel toward the east, the spit buildup on the northwestern side of the river, and the buildup of sand on the northwestern side of "stickout features" throughout the study area, support this interpretation. A similar interpretation is presented in USAE District, Buffalo (1989)[1] and publications of the Ohio Geological Survey.

Geologic setting

The FUDS beach is a thin (2- or 3-m- (6.5- or 10-ft-) thick blanket of sand sitting on top of older lake clays. Lens of organic-rich silts and clays (including peat deposits) are intermingled within the sand body and may be exposed along the shore or in the nearshore, particularly in the troughs between bars. The peat deposits are the result of the relatively modern marsh deposits being exposed on the beach as the barrier migrates back over the marsh.

The mouth of the Toussaint River is fronted by an extensive 460 m-wide by 920 m-long (1,500-ft-wide by 3,000-ft-long) shallow sand shoal, which is asymmetrical toward the east (Figure 10). This shoal represents a trapping of littoral sands which move from the northwest toward the river mouth and are then jetted into a delta-like shoal by river discharge and returning seiche (sudden rise and fall of water levels due to atmospheric conditions) waters which build up in the river during heavy winds from the north. It is probably the presence of this shoal that is responsible for trapping sand that would otherwise have nourished the unstable and eroding beach of the FUDS study area. Three cores were taken by the Buffalo District (U.S. Army Engineer District, Buffalo, 1989) along the proposed channel line lakeward of the Toussaint River mouth in support of the proposed navigation project. Logs from these cores suggest that the shoal consists of a 2- to 3-m (6.5- to 10-ft) thickness of medium-to-fine sand, which includes some coarser sand and a gravel zone overlying lacustrine clays.

Lakeward of the FUDS study site, the shoreline is paralleled by a narrow band of fine-to-medium sandy material which extends approximately 150-300 m (500-1,000 ft) offshore to the 0.6- to 1.2-m (2- to 4-ft) (LWD) contour. This underwater sand extension of the beach includes a series of two to four well-defined shore-parallel sandbars (Figure 11). Lakeward of this sandy zone, the shallow, flat bottom (slope less than 1 :300) is covered with a soft silty-mud layer out to approximately the 3-m (l0-ft) (LWD) contour. This muddy layer pinches out toward the east and offshore, where the bottom becomes a firm blue-clay glacial till, which includes lag-deposit zones of sands and gravels.

The FUDS beach has exhibited shoreline retreat during all recorded shore position surveys (1877 to present). The average retreat rate for the study area is between 0.61 and 0.91 m/year (2 and 3 ft/year), or a total of 68.9 to 103.3 m (226 to 339 ft) since the 1877 baseline survey. The Buffalo District (USAE District, Buffalo, 1989) conducted a shoreline change analysis in support of the design studies for the Toussaint River Navigation Project using additional aerial photography. They found an average recession rate for the shore southwest of the Toussaint River of 0.85 m/year (2.8 ft/year). Long-term shoreline retreat throughout the FUDS study site is exacerbated during periods of high water,

[1] U.S. Army Engineer District, Buffalo. (1989). Detailed project report and environmental assessment on proposed navigation improvements at the mouth of the Toussaint River, Toussaint River Section 107, Buffalo, NY.

when storms with winds from the north can drive the water level up the beach and over the low back beach causing the shore-barrier to be breached.

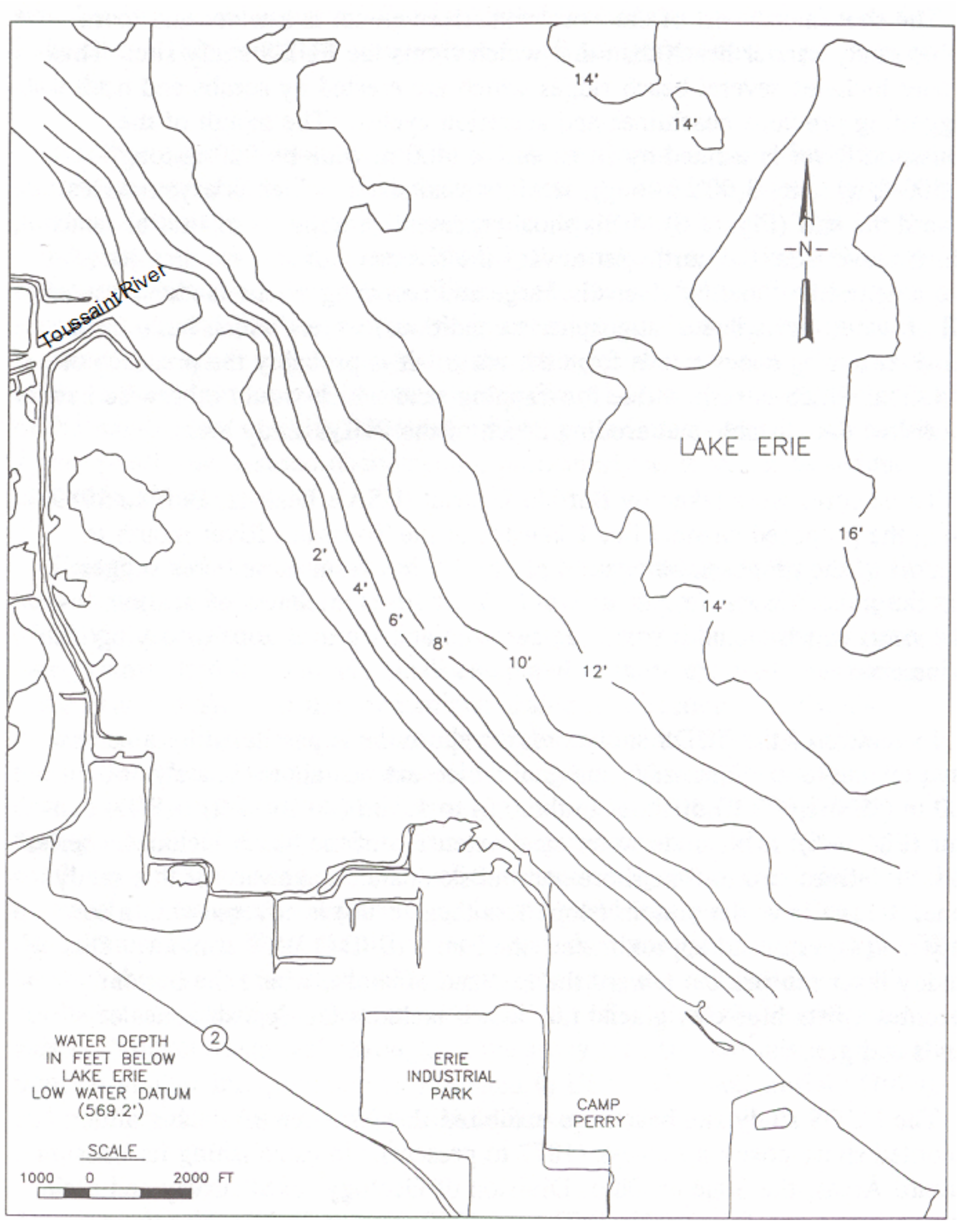


Figure 10. Bathymetry of offshore study area

Figure 11. Aerial photograph of offshore bar structures (Courtesy of Toussaint Gun Club)

3 Methodology

A wide variety of ordnance was recovered during the 1992 cleanup operation at the former Erie Army Depot. These included a 3.5-in. Rocket AT, rifle and smoke grenades, and artillery pieces that ranged from 37 to 165 mm. Though not visually confirmed, 175- and 240-mm artillery ordnance are known to have been proof-fired at the depot. During a site inspection in January 1993, the inspection team observed remaining OEW contamination on the beach and in Lake Erie. Items identified included 60 mm mortars, 81 mm mortars, 90 mm projectiles, and 106mm High Explosive Anti Tank (HEAT) projectiles. During the 1995 dredging project, 60 mm mortars and 106-mm HEAT projectiles were recovered from the separation screen over the scow. Five representative types of ordnance that were part of the Army's arsenal were chosen to represent these types of ordnance found at the site. They are the 60-mm mortar High Explosive (HE) (M49A2), the 81-mm mortar HE (M43A1), 81-mm mortar HE (M56), the 90-mm Gun ATP (M77), and the 106-mm cartridge HE (M344) (Figure 12). Using actual dimensions and weight specifications for these ordnance items (where available), Evans Hamilton Inc. (EHI) designed and constructed SO of nonferrous aluminum and lead. Selection of these construction materials was required for safety reasons because of the UXO presence in the impact area. Magnetometer sweeps to identify potential anomalies prior to SO resurveying and removal operations were required to ensure that UXO had not migrated alongside the SO.

Figure 12. Study SO (16 of 24 without radio transmitters installed)

Approximate tracking of the SO was accomplished with the use of two different types of positioning methodologies, radio and acoustic, while precise positioning was accomplished with the use of a Real-Time Kinematic (RTK) Differential Global Positioning System (DGPS). Radio transmitters (operating on a range from 140 to 218 MHz) were installed in SO placed in shallow water (approximately less than or equal to 2 ft of water), while acoustic transponders (emitting from 25 to 31 kHz) were installed in SO placed in deep water (less than 6 ft deep).

The 60-mm ordnance pieces contained Advanced Telemetry Systems (ATM) radio transmitters, the 81-mm (M43A1) and the 90-mm pieces contained Benthos (UAT-376) acoustic transponders, and the remaining SO contained both a ATM transmitter and Benthos transponder. All of the SO were designed specifically to have the same approximate mass, shape, and size of real ordnance. However, in the case of the five 90-mm pieces, a compromise had to be made to accommodate the transponders. For these pieces, the length to width ratio was maintained, while the overall size was adjusted until they could house the transponder, and have space for enough lead to achieve the weight of the actual round in the water. Ordnance specifications and photographs of the respective SO are presented in Figures 13-17. A summary of the SO is given in Table 3.

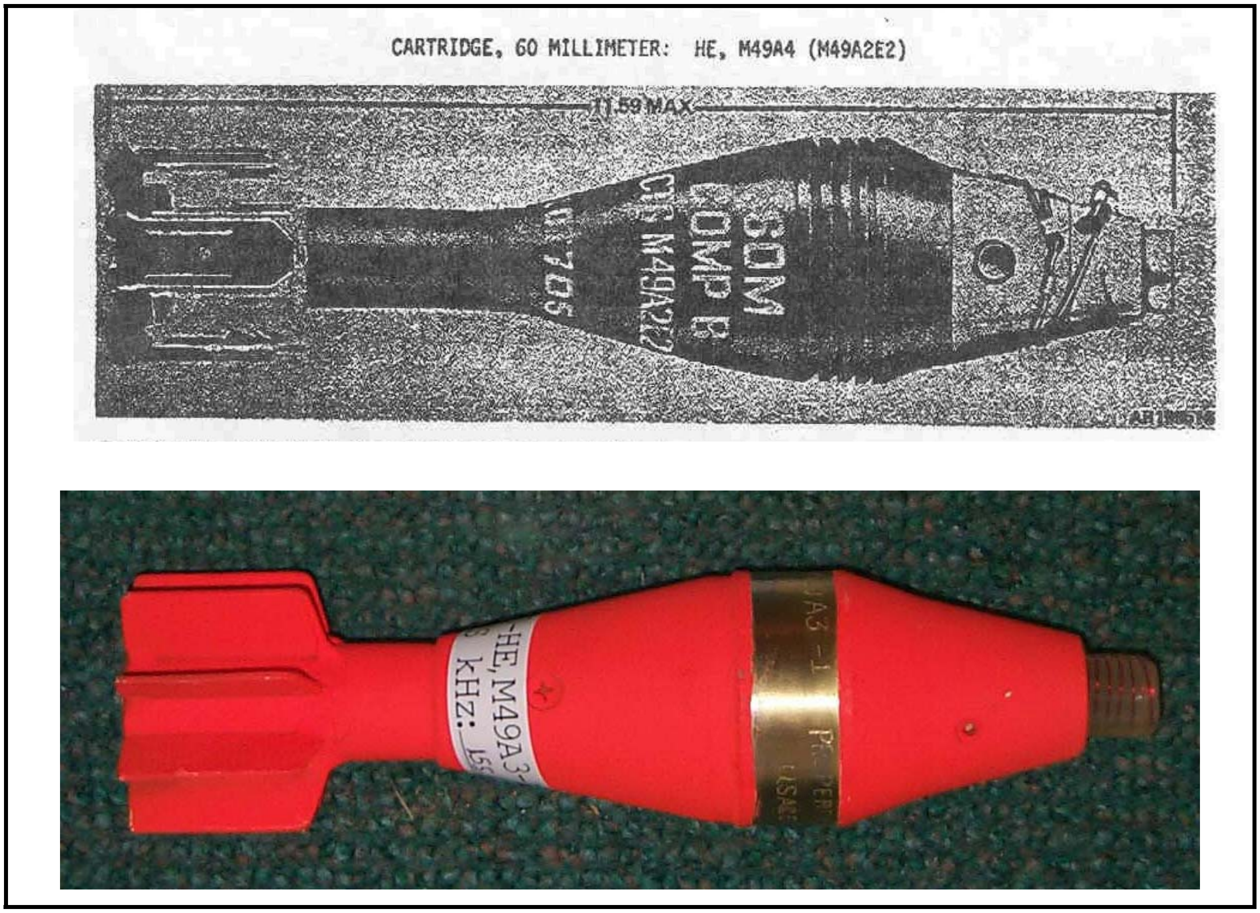


Figure 13. 60-mm HE, M49A2, ordnance specifications and SO photograph

A specimen ordnance was weighed in water at U.S. Army Engineer Research and Development Center (ERDC):

Specification Wt.	Specimen Wt.	Water Wt.
3.07 lb	3.072 lb	2.355 lb

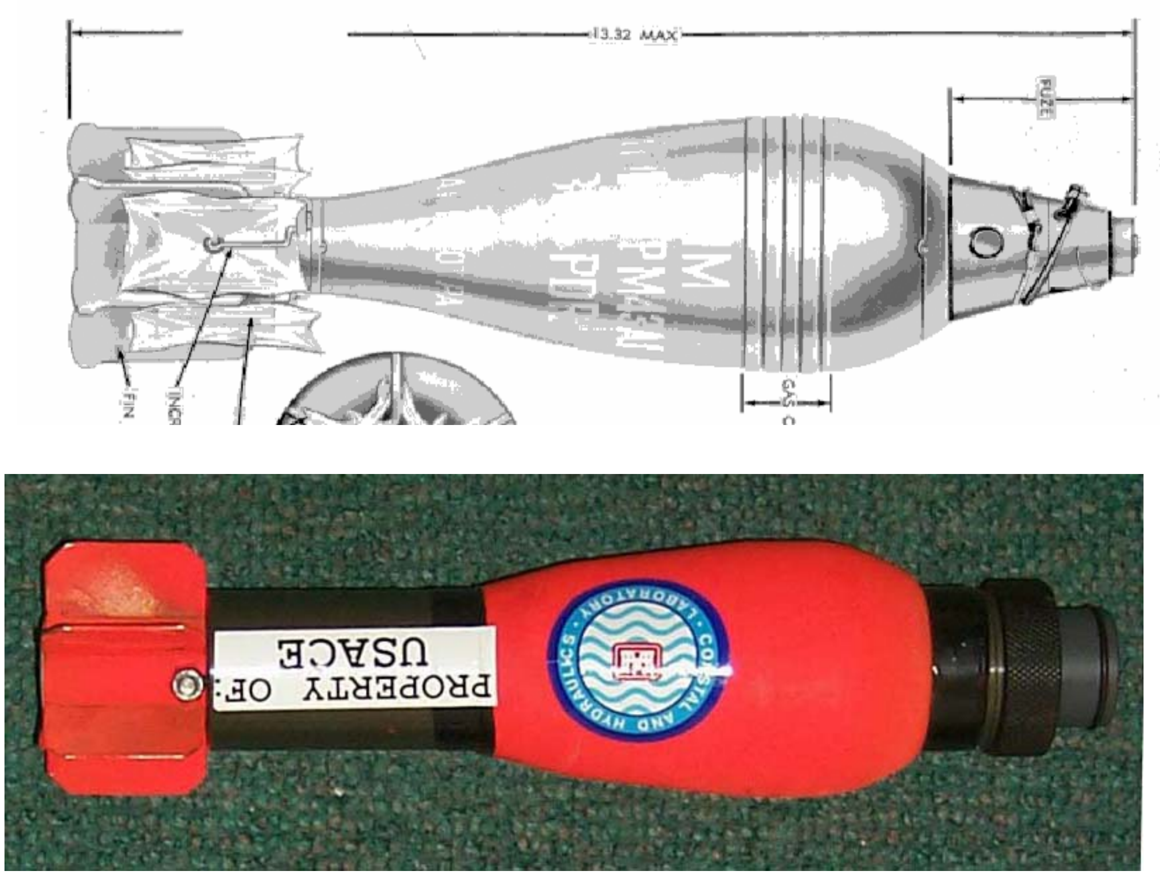


Figure 14. 8-mm, M43A1, ordnance specifications and SO photograph

A specimen ordnance was weighed in water at ERDC:

Specification Wt.	Specimen Wt.	Water Wt.
7.15 lb	7.149 lb	5.408 lb

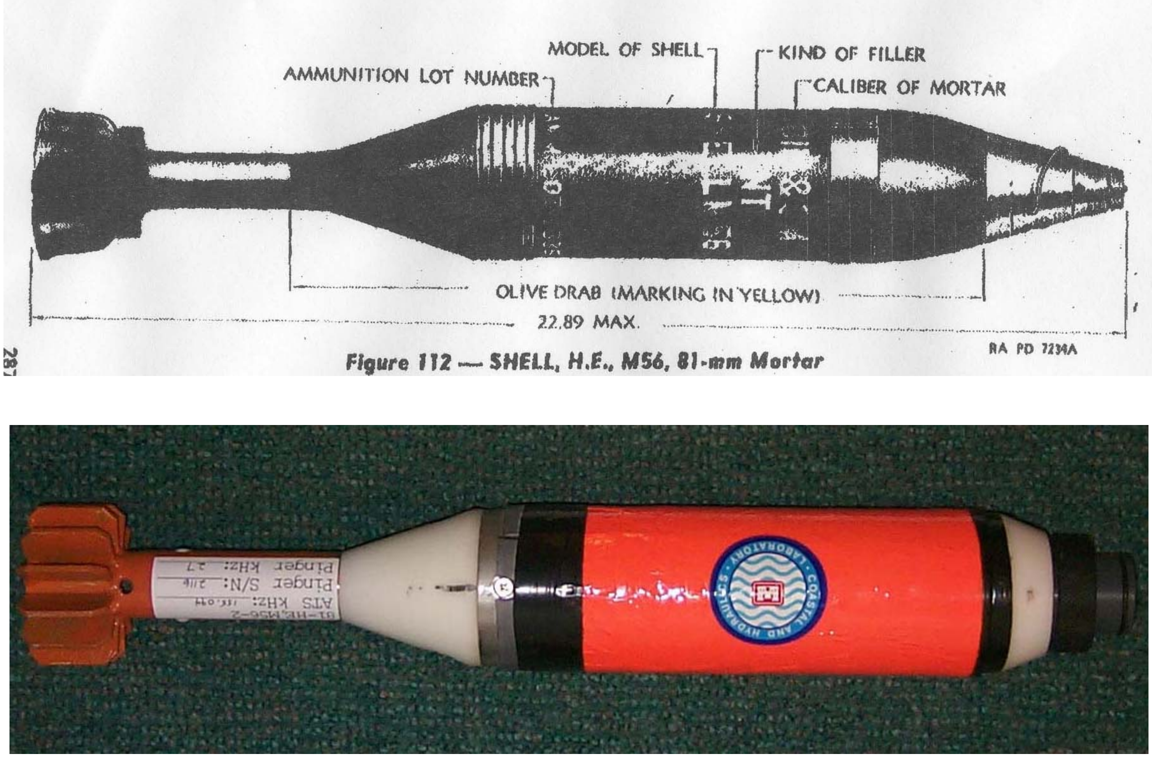


Figure 15. 81-mm, H.E., M56 ordnance specifications and SO photograph

A specimen of this ordnance was not available to weigh, therefore the weight in water was determined using the specified weight in air (10.77 lb) less the volume displacement in fresh water. Weight in water: 7.2 lb.

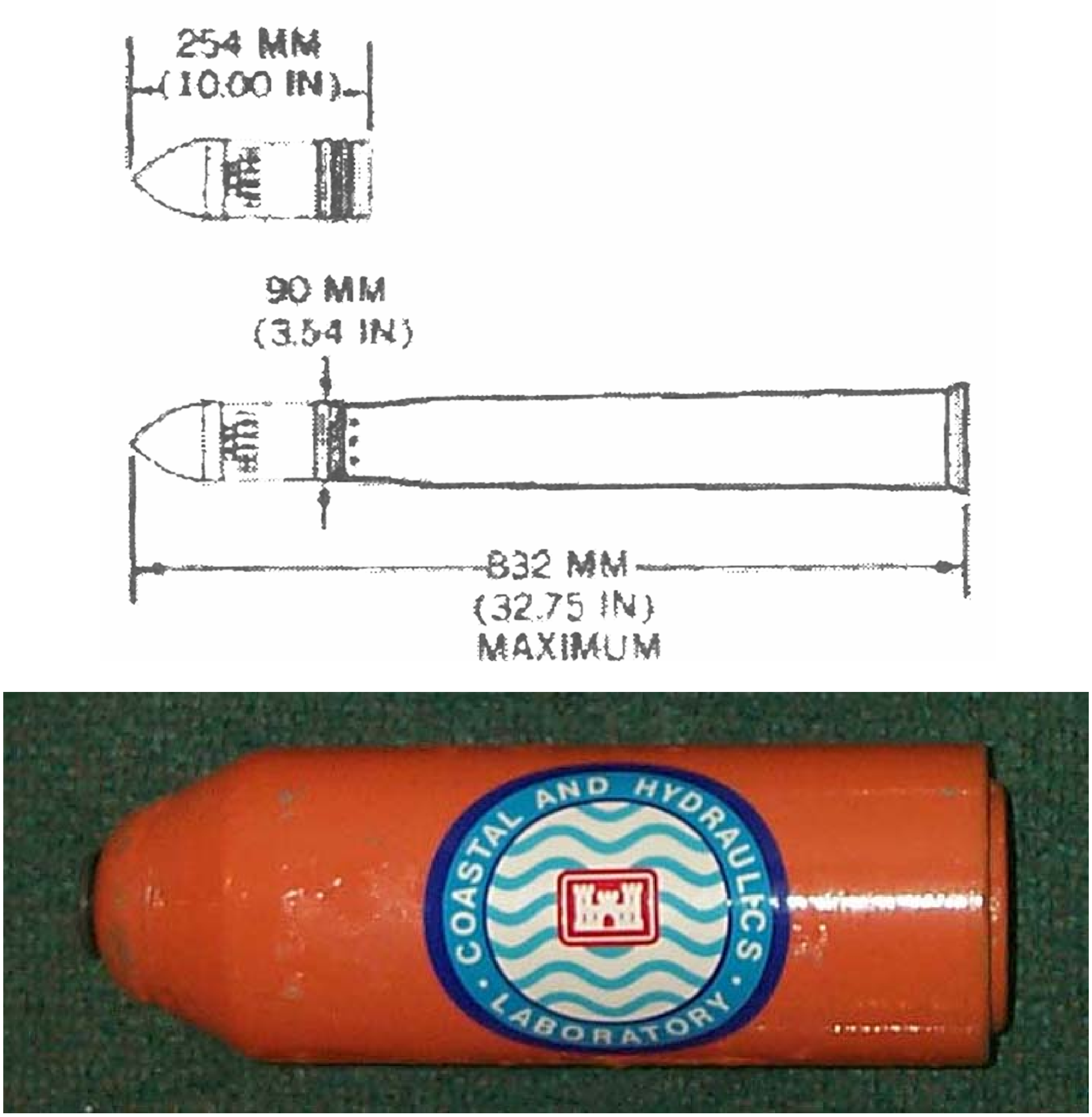


Figure 16. 90-mm, gun, AP-T, M77 ordnance specifications and SO photograph

The exact length and diameter of the 90-mm ordnance could not be duplicated considering that the actual round is a solid object. Therefore, the length/width ratio was maintained in design, until the drogue became large enough to house a transponder and enough lead, to achieve the weight of the actual round in water (20.64 lb).

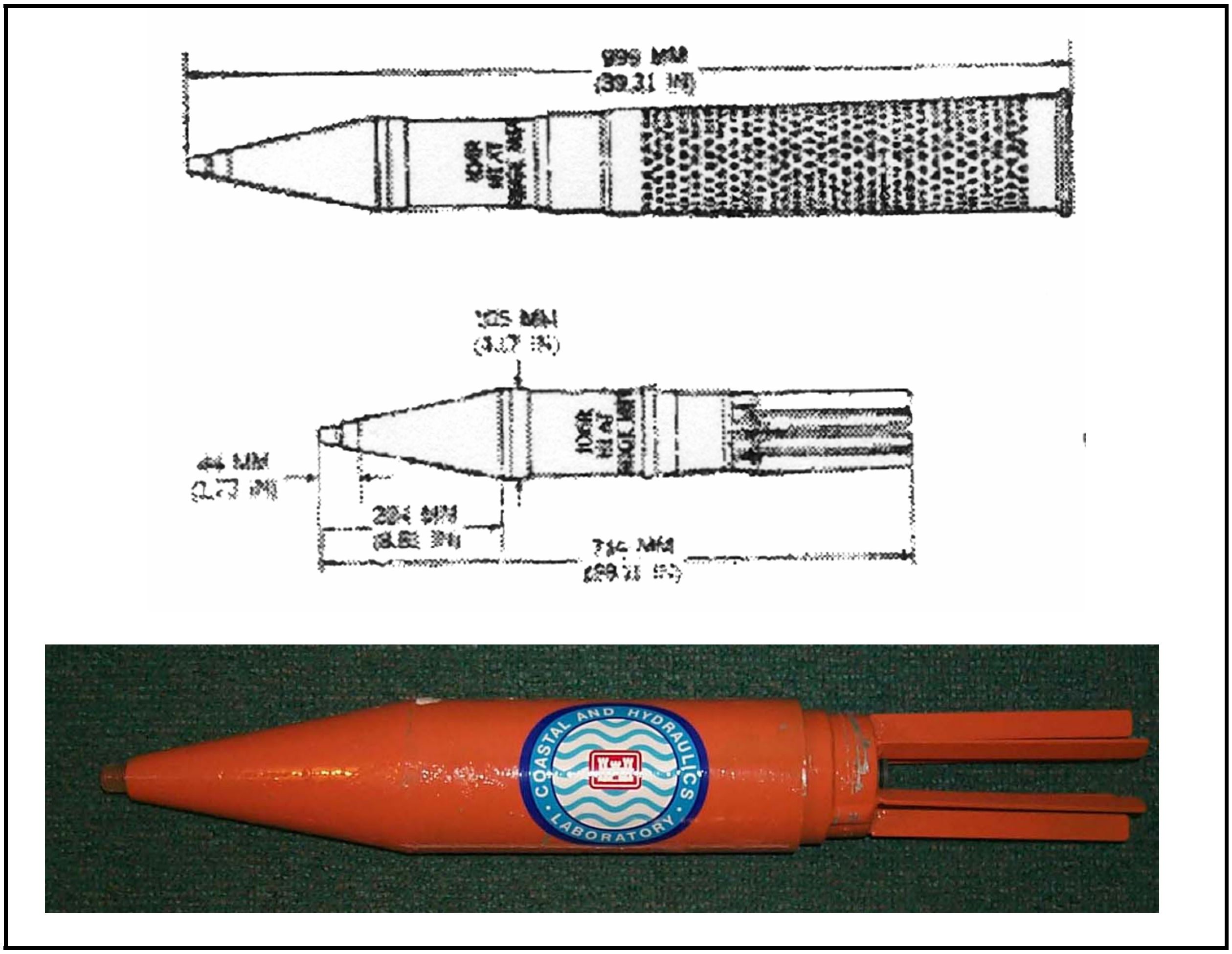


Figure 17. 106-mm: HE, M344 ordnance specifications and SO photograph

A specimen of this ordnance was not available to weigh, therefore the weight in water was determined using the specified weight in air (17.55 lb) less the volume displacement in fresh water. Weight in water: 11.14 lb.

Table 3
SO Specifications

Type	ID	Overall Length In.	Maximum Diameter In.	Weight In Water lb	ATM Frequency kHz	Benthos Frequency kHz
60-mm HE (M49A2)	60-1	9.875	2.375	2.355	155.075	---
	60-2	"	"	"	155.024	---
	60-3	"	"	"	155.094	---
	60-4	"	"	"	155.054	---
	60-5	"	"	"	155.122	---
	60-6	"	"	"	155.084	---
81-mm (M43A1)	81M-1	13.25	3.1875	5.408	---	31
	81M-2	"	"	"	---	25
	81M-3	"	"	"	---	25
	81M-4	"	"	"	---	32
	81M-5	"	"	"	---	31
81-mm HE (M56)	81H-1	22.75	3.0	7.2	155.133	27
	81H-2	"	"	"	155.012	27
	81H-3	"	"	"	155.044	27
	81H-4	"	"	"	155.064	32
90-mm ATP (M77)	90-1	12.69	4.5	20.64	---	32
	90-2	"	"	"	---	28
	90-3	"	"	"	---	29
	90-4	"	"	"	---	28
	90-5	"	"	"	---	29
106-mm HE (M344)	106-1	28.05	4.17	11.14	155.153	30
	106-2	"	"	"	155.134	30
	106-3	"	"	"	155.104	25
	106-4	"	"	"	155.034	29

4 SO Field Operations

Due to deployment of SO in an actual former firing range with the presence of UXO, all activities there required the assistance of the Center of Ordnance Expertise, Huntsville Engineering and Support Center to review the Site Specific Health and Safety Plan (SSHSP) and provide anomaly avoidance support to ensure no contact between field personnel and ordnance occurred.

SO was placed on the lake bed using an SO deployment device (Figure 18). The device was needed to assure that the desired deployment orientation of the SO could be achieved, and to establish a deployment location when visibility was

Figure 18. SO deployment device. Note the gentle bathymetry slope of study site illustrated by depth of water that the two people in upper right-hand corner are standing in and the waves shoaling on the first sand bar offshore

limited. At times, visibility in the water was as little as a few inches. A Trimble Differential Global Positioning System (DGPS) with Real-Time Kinematic (RTK) tracking capabilities was used to survey the SO horizontal and vertical position. Some deployments made during the winter required cutting a hole through the ice at the deployment locations.

The RTK DGPS required that a GPS receiver and a radio transmitter be placed at a precisely known geographic location (i.e., a base RTK-DPGS control point) where a RTK rover (Figure 19), which is placed at each surveyed position, could receive the radio transmissions without interruption. The GPS receiver collected position data referenced to World Geodetic Survey 1984 (WGS-84) from satellites. The relationship between WGS-84 data and local control points (National Geodetic Survey 'NGS' monuments) expressed as a local map grid with elevations above sea level (i.e., local datum) was then determined. The accuracy of the RTK GPS fix varied from SO to SO as a function of distance from base station, but specifications of the system's precision for real-time and post-processed surveying are 1 cm + 1 parts per million (ppm) horizontal (approximately 0.03 ft), and 2 cm + 1 ppm for vertical fixes (approximately 0.065 ft).

Figure 19. The Trimble Model 4700 RTK Rover positioning 60-mm SO

The basic procedure established for each drogue deployment involved:

a. Determination of deployment location, SO type, orientation (parallel or perpendicular to shore) and distance from shore.

b. The desired location was then checked for anomaly (existing ordnance) avoidance and approved.

c. SO placement on the lake bed.

d. RTK position fix; electronic storage of coordinates and handwritten notes of general location, orientation, bottom type, and water depth.

e. Release SO from deployment tool and ensure no post-release SO movement occurred.

The shallow-water deployment consisted of wading out into the water while practicing anomaly avoidance and placing (and positioning with a mobile-pack RTK DGPS) the SO in locations determined to be anomaly-free. Placement of the SO in deep water involved the use of a shallow-draft boat. The deployment process consisted of establishing safe anchoring locations (practicing anomaly-avoidance), and placing (and positioning with RTK DGPS) the SO in anomaly-free locations.

The procedure used during the surveys was to use the RTK rover to return to the last surveyed position of each piece of SO and visually attempt to relocate it or tap on it with the survey rod; this worked well with SO that did not experience significant movement). If the SO was not found using this method, (depending on which SO was being located) either the acoustic or radio tracking system was used to approximately locate the SO, then its precise position was determined with the RTK DGPS. An underwater video camera system was brought along on each survey. The portable drop-camera (with optional underwater lights), mounted on a pole and coupled to a surface video screen, was used to locate the SO if lake visibility permitted. Due to poor water clarity, the system was frequently needed to make a visual inspection of the SO. Where possible, the camera was used to read a hand-held compass temporarily mounted on the SO, thereby determining its approximate orientation. SO orientation was defined by the bearing line measured from the SO base to the fuse, referenced to magnetic north. The survey rod tip was placed on top of the SO, as close to its body midsection as possible, to measure its position as accurately and precisely as could be practically accomplished.

The radio tracking method involved monitoring a compact receiver that indicated distance to the transmitter inside the SO by varying the level of audio tone emitted by the receiver. Transmitter-equipped SO placed relatively close were fitted with different frequencies. After all available frequencies were used, redundant frequency-equipped SO were separated by relatively long distances over the 3-mile-long study area. Depending on lake water level (the SO may have been “dry”), a two-man party (one using the magnetometer, the other monitoring the radio receiver and carrying the RTK DGPS mobile-pak) approximately located the transmitter, and, conditions permitting, visually located the SO and positioned it by holding the RTK-DGPS antennae over it.

The acoustic method involved immersing a hand-held acoustic interrogator transducer into the water to determine the underwater range (with a range of 750 m) and direction between the SO transponder and interrogator. This system displays range and bearing strength to a portable deck unit and is accurate within $\pm$1 m. Operational life of the UAT-376EL transponders with lithium batteries was 24 months or 900,00 replies. As previously described for the radio-located SO, after being located acoustically, the SO was visually located (with or without the drop camera system), then precisely positioned with the RTK DGPS. The deepwater SO were approximately located by the acoustic method from a boat, then precisely positioned with the drop camera/RTK DGPS process previously described.

Tests were conducted in Lake Erie to evaluate the acoustic positioning system’s capability to range in shallow water and also to investigate its response when buried in sand. The system accurately ranged in water depths as shallow as 2 ft at a separation distance of 300 ft, but lost track if a sufficiently “high” enough sandbar was between the SO transponder and interrogator. A transponder was buried 1.5 ft (with transponder head oriented horizontally) in sand and the system still accurately ranged in 2 ft deep water at the 300-ft distance.

The radio method involved rotating a directional antenna while the receiver indicated range by increasing or decreasing an audio signal in response to the antenna's orientation to the transmitter. In other words, when the antenna was pointed directly toward the transmitter, the audio signal was loudest. When the transmitter was close to the receiver (approximately 10 ft), the antenna was disconnected, and the receiver's audio signal was used to approximately locate the SO. Battery life on the Advanced Telemetry Systems Inc. Model F1245 (Fish Body Implant) was 950 days. Testing results of this positioning system were similar to the acoustic system. The receiver/YAGI system ranged to a transmitter placed in 2-ft-deep water at 300 ft, when it was lying exposed on the lake bed, and when it was buried in sand 1.5 ft deep with its antenna oriented horizontally.

SO positions were surveyed on five occasions from December 2001 to July 2003, when the SO were located by divers and recovered.

Deployment, September 2001

The initial SO deployment effort commenced the week of September 17, 2001. Security measures related to the September 11, 2001, terrorist attacks in the U.S. affected the field effort schedule and procedures. The SO appeared extremely realistic to the public, and it was decided that truck freight directly from EHI's Seattle, WA office to the Port Clinton, OH study area was a prudent measure. Increased security measures at the Camp Perry Army Reserve Base and Davis-Bessie Nuclear Power Plant also created some delay in the deployment procedures.

The initial deployment of SO was accomplished on September 20-21, 2001. The deployment locations for the 16 pieces of SO that were deployed are given in Table 4. There were two general deployment locations. One was in the vicinity of the Toussaint River navigation channel (Figure 20), to determine if UXO located in, or transported to, this area could move into the navigation channel. The other area was approximately 3 miles to the southeast, near the southeastern boundary of the former Erie Army Depot and Camp Perry (Figure 21). Five pieces of SO that were placed at this location were put in two lines perpendicular to the shore. This was done to determine how coastal processes might spread UXO along the shore. In the area of the Toussaint River, three pieces of SO (60-1, 60-2, and 60-3) were placed at the water's edge, while in the southeastern area, SO 60-4 was placed at the waterline (Table 4). The individual deployment locations at these two general areas were selected by ERDC and Buffalo District personnel in an attempt to place the SO in as many different conditions (i.e., bottom types, relative location inside or outside of sandbars, etc.) as possible. While it was realized that actual ordnance can exist in three basic conditions on the lake bottom (buried, partially-buried, and lying proud (completely unburied and lying on bottom)), all SO were placed directly upon the bottom (lying proud) in an attempt to optimize any movement potential during the short study duration.

Table 4
September 2001 SO Deployment

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS	Datasonics Pinger			
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation survey ft)	Transmitter Serial Number (kHz)	Serial Number	Channel Number	Frequency (kHz)	Comments
60	60-HE, M49A3-1	A1	9/20/2001	15:50	0	41 35 19.74894	83 03 39.86196	1815015.648	700793.904	569.878	155.075	--	--	--	1000NW Channel. At water's edge. Fuse toward cooling tower, tail toward channel. On sand w/some gravel.
90	90-APT-3	A1	9/20/2001	16:05	2.1'	41 35 20.83759	83 03 37.59214	1815188.832	700902.982	567.853	--	2042	4	29	1000NW Channel. ~30' lakeward of single sand bar. Perpendicular to shoreline, fuse pointed shoreward. On sand.
106	106-HE M344-1	A1	9/20/2001	16:20	3.5'	41 35 21.04607	83 03 36.83068	1815246.828	700923.711	566.496	155.153	2119	5	30	1000 NW Channel. Shore parallel, fuse toward channel. On sand.
90	90-APT-2	A2 (north bank)	9/20/2001	16:45	~2.5'	41 35 13.66203	83 03 46.77625	1814486.279	700181.207	567.748	--	2041	3	28	River Area, North side. At S. edn of wood fence. Parallel to shore. Fuse lakeward. On mud bottom.
81	81-M43A1-1	A2 (south bank)	9/20/2001	11:20	~3'	41 35 12.19173	83 03 47.13021	1814458.421	700032.565	568.254	--	2113	6	31	River Area, South side. Align wood fence on N. bank w/tree. Drogue perpendicular to river flow. On mud bottom.
81	81-HE, M56-1	A3	9/20/2001	11:55	10"	41 35 11.02227	83 03 25.80296	1816078.3	699903.79	568.968	155.113	2040	2	27	Placement Site. Parallel with channel center line. Fuse pointed lakeward. On sand bottom.
90	90-APR-1	A3	9/20/2001	12:45	~3.5'	41 35 11.59057	83 03 18.04328	1816668.319	699957.55	566.591	--	2114	7	32	Placement Site. Perpendicular to channel center line. Fuse pointing toward channel center line. On sand bottom.
60	60-HE, M49A3-2	A4	9/20/2001	13:45	0	41 35 04.61414	83 03 35.09671	1815367.911	699259.717	570.622	155.024	--	--	--	1000SE Channel. Align with cut end of huge stump, inshore of big tire. Shore perpendicular. Fuse pointing shoreward. On sand.
81	81-M43A1-2	A4	9/20/2001	14:00	?	41 35 08.56219	83 03 11.64365	1817152.677	699647.945	566.7	--	2039	1	25	1000SE Channel. Fuse pointed lakeward. On sand bottom.
60	60-HE, M49A3-3	A5	9/20/2001	14:50	0	41 34 57.07379	83 03 11.23401	1817176.431	698484.956	570.015	155.094	--	--	--	2500 SE Channel. On third sand bar lakeward from shore. Shore parallel. Fuse pointing toward Camp Perry.
90	90-APT-5	A5	9/20/2001	15:19	4'	41 35 02.44440	83 03 01.69631	1817904.669	699023.953	565.919	--	2118	4	29	2500SE Channel. Shore Perpendicular. Fuse lakeward. On sand bottom.
60	60-HE, M49A3-4	A6	9/21/2001	9:27	0	41 33 20.83523	83 01 40.55182	1824008.763	688701.551	570.316	155.054	--	--	--	Camp Perry Area. Water's edge. Fuse lakeward. On sand w/some gravel.
81	81-M43A1-3	A6	9/21/2001	10:03	3.9'	41 33 23.33949	83 01 35.39808	1824402.106	688952.648	566.617	--	2115	1	25	Camp Perry Ara. Sandy bottom. Fuse lakeward.
81	81-HE,M56-2	A6	9/21/2001	9:46	2.4'	41 33 22.13300	83 01 38.05706	1824199.221	688831.756	567.897	155.012	2116	2	27	Camp Perry Area. Sandy/clay bottom. Fuse lakeward.
90	90-APT-4	A6	9/21/2001	9:41	2.6'	41 33 22.05756	83 01 37.96571	1824206.12	688824.078	567.881	--	2117	3	28	Camp Perry Area. Sandy/clay bottom. Fuse lakeward.
106	106-HE M344-2	A6	9/21/2001	10:14	3.9'	41 33 23.25906	83 01 35.29783	1824409.678	688944.461	566.759	155.134	2043	5	30	Camp Perry Area. Sandy bottom. Fuse lakeward.

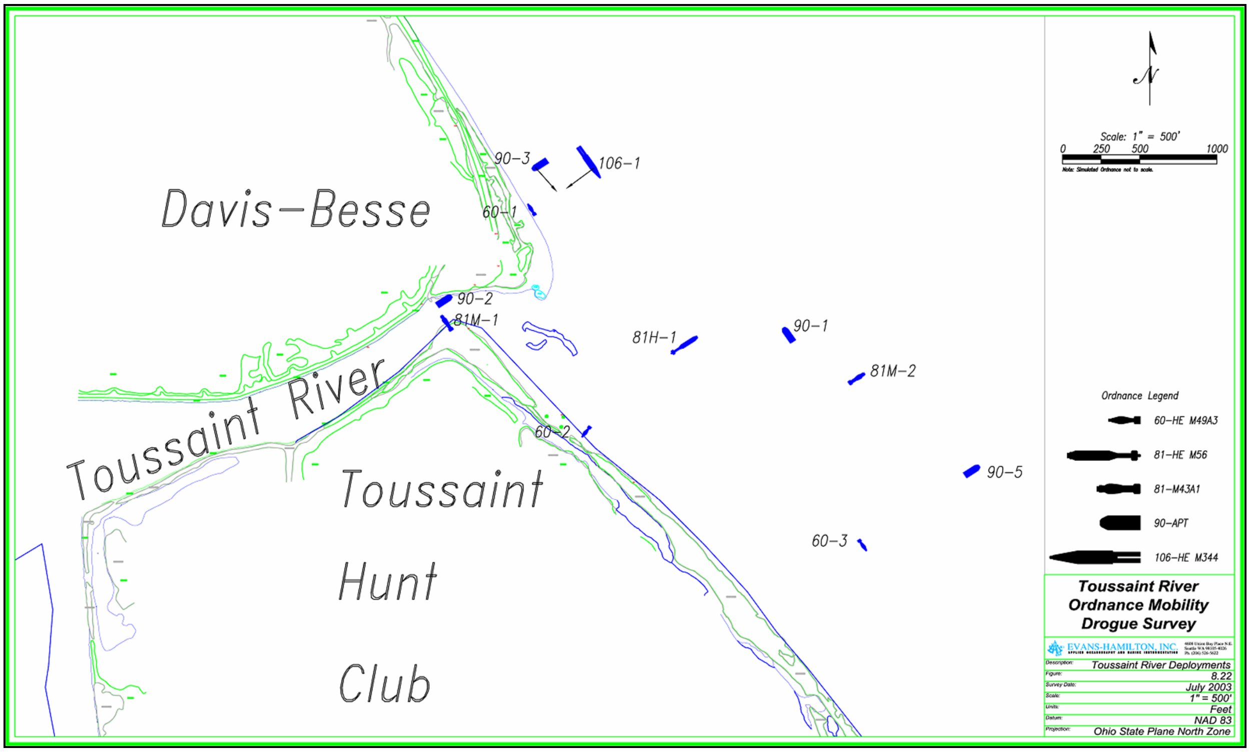


Figure 20. SO deployed in vicinity of Toussaint River

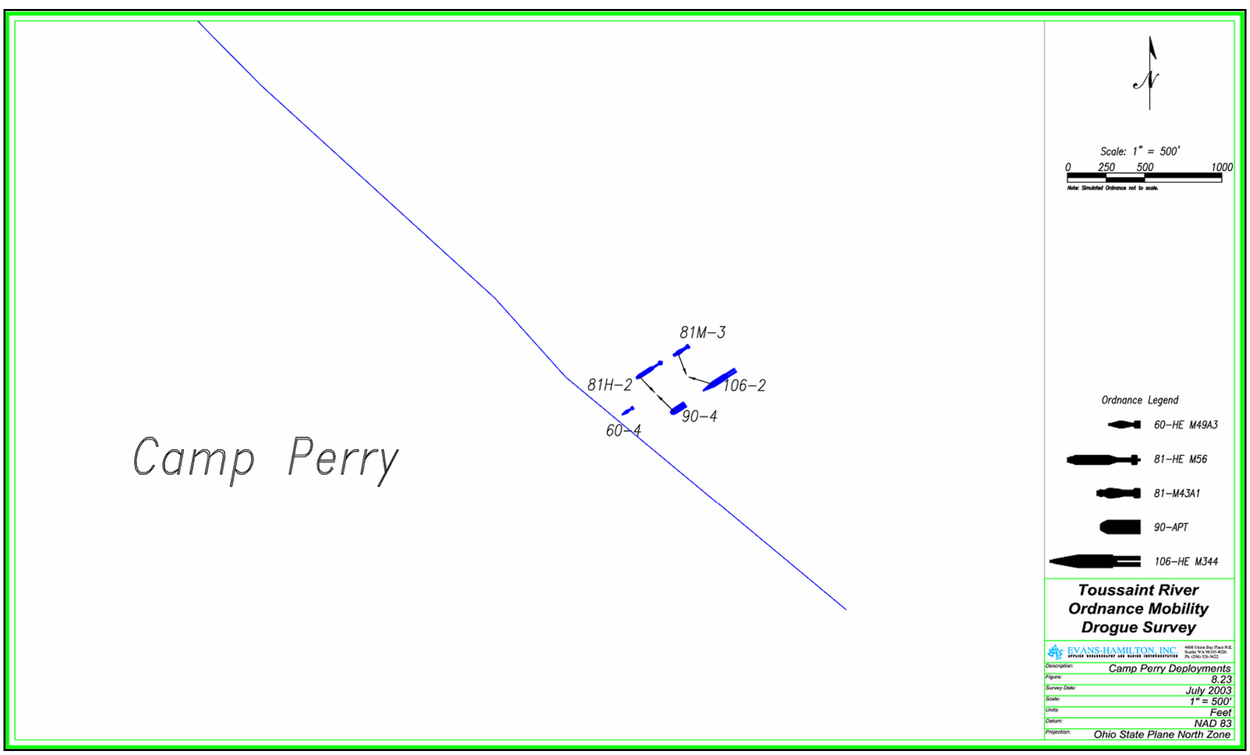


Figure 21. SO deployed in vicinity of Camp Perry

Survey No. 1, December 2001

The first post-deployment survey of SO positions took place on December 4-5, 2001 (approximately 10 weeks after deployment). Two pieces of SO that were placed at the waterline (60-1 and 60-2) on both sides of the Toussaint River were not relocated. Attempts to locate them by radio failed, indicating that they probably had not moved offshore, and that someone may have removed them from the beach. The SO that was on the north side of the Toussaint River, 90-2, had apparently rolled down the sideslope of the river channel. Its net movement from the time it was deployed was 7.39 ft. With the exception of SO 106-1, which moved 1.51 ft, the remainder of the SO that were relocated had moved less than 1 ft. As a result of increased wave conditions on the second survey day, 81M-3 and 90-4 could not be surveyed. Acoustic ranging on these pieces of SO indicated that they were approximately still at their deployed locations. Video imaging of the SO showed that bottom material had moved around and over some pieces (Figures 22, 23, 24, 25, and 26). The results of survey No. 1 are given in Tables 5 and 6. Table 5 primarily presents field observations and Table 6 presents transport information for each piece of SO from its initially-deployed location.

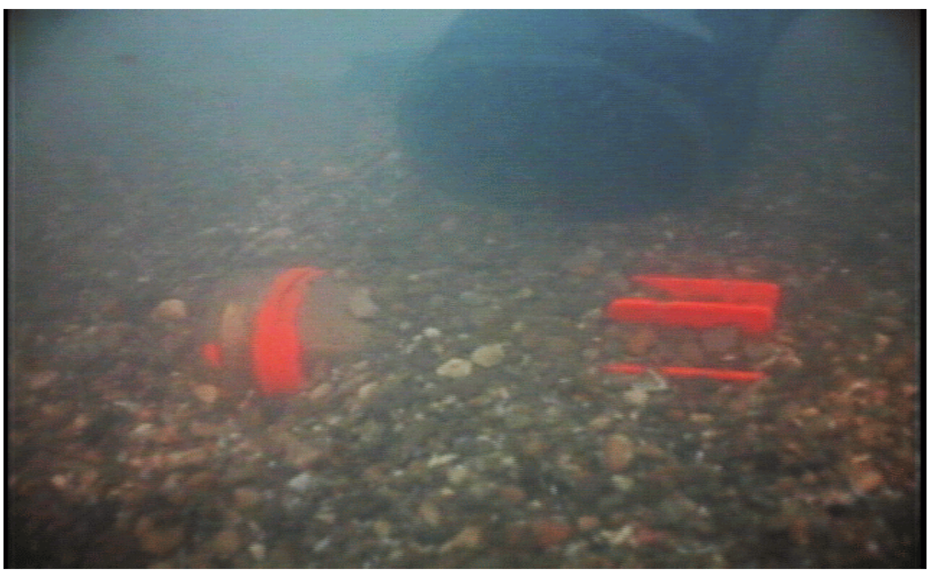


Figure 22. SO 60-4, December 4, 2001

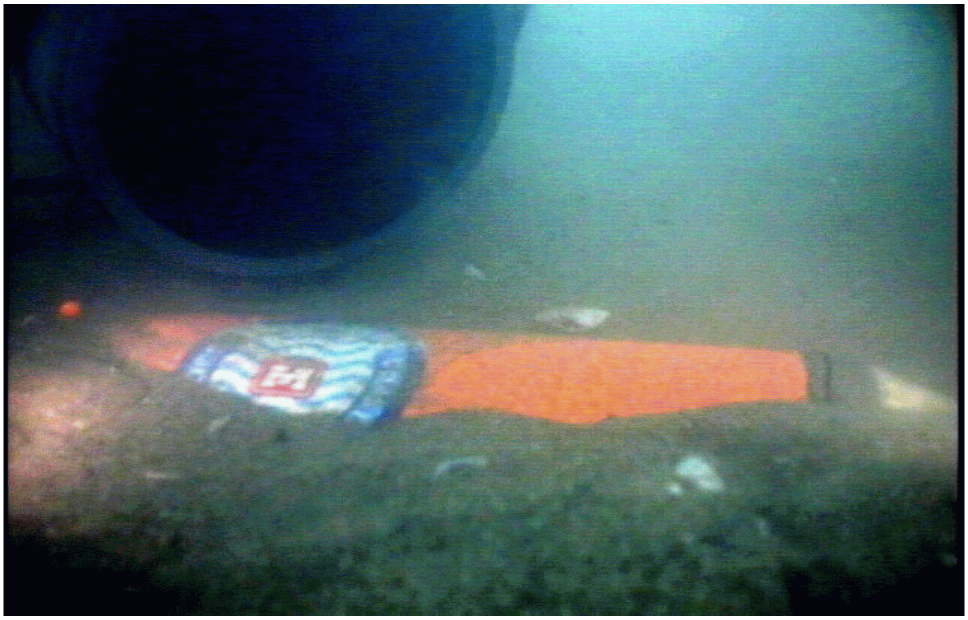


Figure 23. SO 81H-2, December 4, 2001

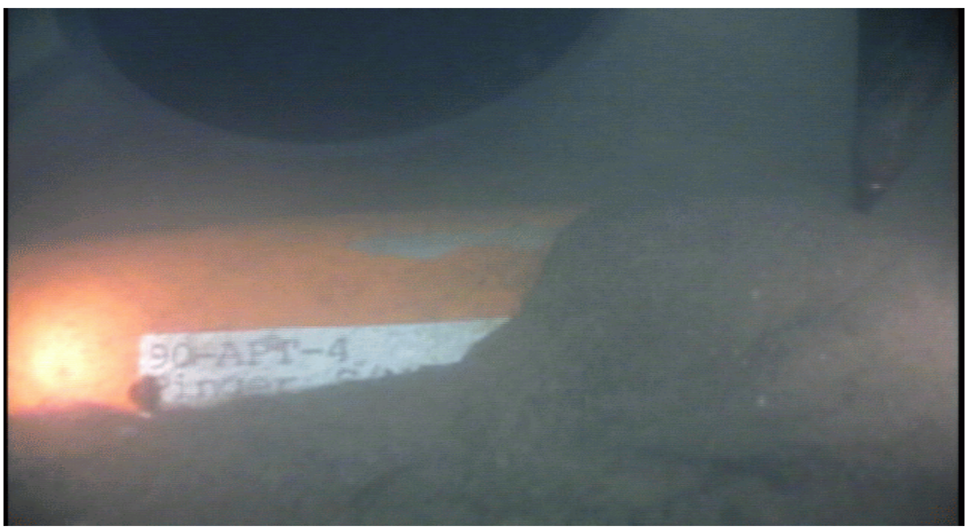


Figure 24. SO 90-4, December 4, 2001

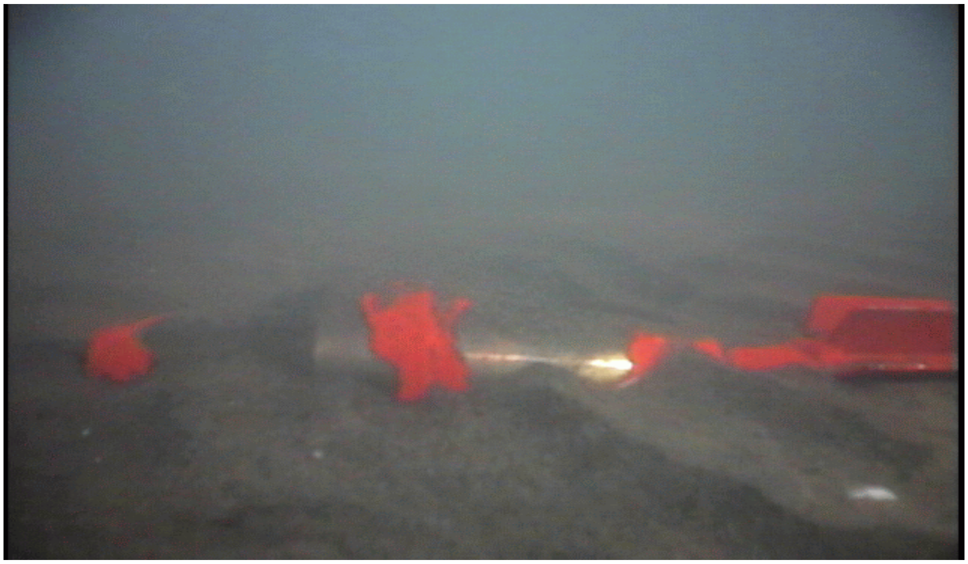


Figure 25. SO 60-3, December 5, 2001

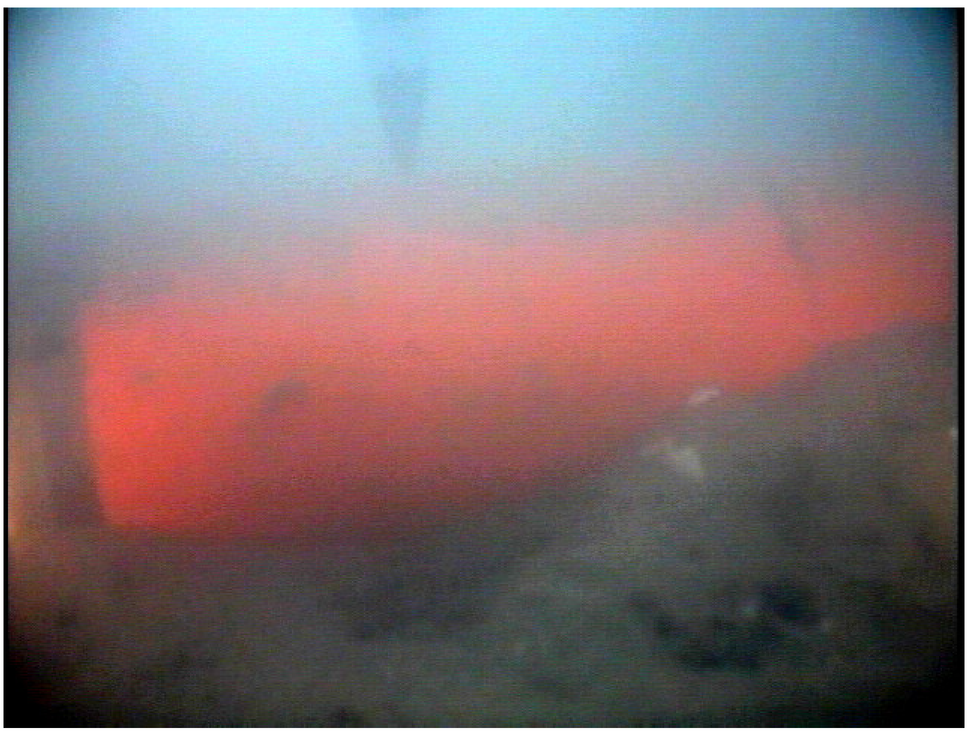


Figure 26. 90-APT-5, December 5, 2001 (survey rod tip can be seen on top of SO)

Table 5
Observations from Survey No. 1, December 2001

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	Deployment Notes = Normal font **Dec. 2001 Notes = Italic Bold**
60	60-HE, M49A3-1	A1	9/20/2001		0						155.075	8	--	--	--	1000NW Channel. At water's edge. Fuse toward cooling tower, tail toward channel. On sand w/some gravel. ***Not Located.***
90	90-APT-3	A1	12/5/2001	9:45	3'	41 35 20.83722	83 03 37.59806	1815188.765	700902.982	567.946	--		2042	4	29	1000NW Channel. ~30' lakeward of single sand bar. Perpendicular to shoreline, fuse pointed shoreward. On sand. ***Same orientation, buried 6".***
106	106-HE M344-1	A1	9/20/2001	16:20	3.5'	41 35 21.04287	83 03 36.85537	1815245.333	700923.711	566.719	155.153	15	2119	5	30	1000 NW Channel. Shore parallel, fuse toward channel. On sand bottom. ***Same.***
90	90-APT-2	A2 (north bank)	12/4/2001	15:51	~5.5'	41 35 13.59898	83 03 46.72818	1814490.270	700181.207	562.739	--		2041	3	28	River Area, North side. At S. edn of wood fence. Parallel to shore. Fuse lakeward. On mud bottom. ***Rolled down into river, buried ~1 ft.***
81	81-M43A1-1	A2 (south bank)	12/4/2001	15:15	~3'	41 35 12.19338	83 03 47.13298	1814458.591	700032.565	567.949	--		2113	6	31	River Area, South side. Align wood fence on N. bank w/tree. Drogue perpendicular to river flow. On mud bottom. ***Same orientation.***
81	81-HE, M56-1	A3	12/5/2001	10:30	10"	41 35 11.02125	83 03 25.80870	1816078.237	699903.79	569.269	155.113	11	2040	2	27	Placement Site. Parallel with channel center line. Fuse pointed lakeward. On sand bottom. ***No change.***
90	90-APR-1	A3	12/5/2001	10:49	~3.5'	41 35 11.59221	83 03 18.04920	1816668.243	699957.55	566.798	--		2114	7	32	Placement Site. Perpendicular to channel center line. Fuse pointing toward channel center line. On sand bottom. ***Buried 3", orientation unknown.***
60	60-HE, M49A3-2	A4	9/20/2001		0				699259.717		155.024	3	--	--	--	***Not Located.***
81	81-M43A1-2	A4	12/5/2001	12:04	~4'	41 35 08.56675	83 03 11.65336	1817152.311	699647.945	566.206	--		2039	1	25	1000SE Channel. Fuse pointed lakeward. On sand bottom. ***Fins toward shore, too deep to hold boad steady for visual.***

(Continued)

Table 5 (Concluded)

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
Mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	Deployment Notes = Normal font **Dec. 2001 Notes = Italic Bold**
60	60-HE, M49A3-3	A5	12/5/2001	11:17	6"	41 34 57.07114	83 03 11.23694	1817176.362	698484.956	569.753	155.094	9	--	--	--	2500 SE Channel. On third sand bar lakeward from shore. Shore parallel. Fuse pointing toward Camp Perry. ***Rotated, fuse now toward river.***
90	90-APT-5	A5	12/5/2001	12:30	4'+	41 35 02.44274	83 03 01.70107	1817904.669	699023.953	565.919	--		2118	4	29	2500SE Channel. Shore Perpendicular. Fuse lakeward. On sand bottom. ***Hit drogue w/range pole but couldn't hold boat still enough to take fix.***
60	60-HE, M49A3-4	A6	12/4/2001	10:55	0	41 33 20.83576	83 01 40.55455	1824008.829	688701.551	569.411	155.054	4	--	--	--	Camp Perry Area. Water's edge. Fuse lakeward. On sand w/some gravel. ***75% buried.***
81	81-M43A1-3	A6	9/21/2001	10:03	3.9'	41 33 23.33805	83 01 35.40167	1824402.106	688952.648	566.617	--		2115	1	25	Camp Perry Ara. Sandy bottom. Fuse lakeward. ***Too deep to locate.***
81	81-HE,M56-2	A6	12/4/2001	12:10	2.4'	41 33 22.12495	83 01 38.06260	1824199.069	688831.756	567.037	155.012	1	2116	2	27	Camp Perry Area. Sandy/clay bottom. Fuse lakeward. ***Buried ~2".***
90	90-APT-4	A6	12/4/2001	12:37	2.6'	41 33 22.05108	83 01 37.97143	1824205.954	688824.078	567.798	--		2117	3	28	Camp Perry Area. Sandy/clay bottom. Fuse lakeward. ***Buried ~.5".***
106	106-HE M344-2	A6	9/21/2001	10:14	3.9'	41 33 23.25761	83 01 35.30142	1824409.678	688944.461	566.759	155.134	14	2043	5	30	Camp Perry Area. Sandy bottom. Fuse lakeward. ***Too deep to locate.***

Table 6
Transport of SO from Last Surveyed and Surveyed Locations During Survey No. 1

Deployment Zone	SO Description		Mobility				Comments
	mm	Serial Number	Δ East (survey ft)	Δ North (survey ft)	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	Elevation on deployment was lake bed at drogue. Elevation Dec 2001 from top of drogue body.
A1	60	60-HE, M49A3-1					GONE. No response on ATS.
A1	90	90-APT-3	-0.067	0.145	.162@335°	0.093	Buried ~6”. Oriented as deployed.
A1	106	106-HE M344-1	-1.495	-0.132	1.51@265°	0.223	Oriented as deployed.
A2 (north bank)	90	90-APT-2	3.991	-6.219	7.39@140°	-5.009	Rolled down into river thalwag. Buried ~1 ft. Rotated 90°.
A2 (south bank)	81	81-M43A1-1	0.17	0.355	.393@025°	-0.305	Approx. half of drogue diameter exposed. Oriented as deployed.
A3	81	81-HE, M56-1	-0.063	0.075	.098@319°	0.301	Sitting proud. Oriented as deployed.
A3	90	90-APT-1	-0.076	0.341	.349@347°	0.207	Buried 3” under sand crust. Orientation unknown.
A4	60	60-HE, M49A3-2					GONE. No response on ATS.
A4	81	81-HE, M43A1-2	-0.366	0.635	.733@330°	-0.494	Sitting proud. Oriented as deployed.
A5	60	60-HE, M49A3-3	-0.069	-0.094	.117@216°	-0.262	Rotated ~ 180°. Partially buried.
A5	90	90-APT-5	~0	~0	~0	~0	Located at deployment coordinate, but couldn’t hold steady enough to fix position or acquire video.
A6	60	60-HE, M49A3-4	0.066	0.203	.213@018°	-0.905	Approx. half of drogue diameter buried. Oriented as deployed.
A6	81	81-M43A1-3	?	?	?	?	Too deep to wade, too far to run boat.
A6	81	81-HE, M56-2	-0.152	-0.666	.683@193°	-0.86	Buried 2”. Oriented as deployed.
A6	90	90-APT-4	-0.166	-0.506	.533@198°	-0.083	Buried 1/2”. Oriented as deployed.
A6	106	106-HE M344-2	?	?	?	?	Too deep to wade, too far to run boat.

Survey No. 2, May 2002

The second post-deployment survey of SO positions took place on May 23-25, 2002 (approximately 33 weeks after deployment). At this time, the water level in Lake Erie was higher (approximately 1 ft higher than the water level during SO deployment), and the wave state was rough. It was possible to wade to only two SO locations, and the previous survey procedure could not be followed. The survey of the SO was conducted primarily by using a skiff and the Datasonics interrogator. Using the RTK rover, the skiff was positioned as near as possible to the SO locations determined during the December survey, and the interrogator was lowered to near the lake bed on the end of a pole. The range to each piece of SO from its approximate December-surveyed location was recorded from the interrogator range readings, but accuracy could not be maintained due to movement of the skiff under the wind and wave action. Several pieces of SO, 60-4, 81M-3, 81H-2, 90-4, and 106-2, could not be surveyed at all because of the conditions. During the survey of the two pieces of SO that were located by wading to them, 81M-1 and 81H-1, problems with the RTK rover resulted in inaccurate position fixes. The results of survey No. 2 are shown in Table 7. Due to the poor positional accuracy that resulted from the conditions, there is no table of new positions reported for survey No. 2, and Tables 7 and 8 have only rough estimates from acoustic measurements of distance from last surveyed position.

Table 7
Observations from Survey No. 2, May 2002

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting- survey ft)	State Plane (Northing- survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	Deployment Notes = Normal font **Dec. 2001 Notes = Italic Bold** MAY 2002 NOTES = ALL CAPS
60	60-HE, M49A3-1	A1	9/20/2001		0						155.075	8	--	--	--	1000NW Channel. At water's edge. Fuse toward cooling tower, tail toward channel. On sand w/some gravel. ***Not Located.***
90	90-APT-3	A1	5/24/2002	10:00	~4.5'	41 35 20.83722	83 03 37.59806	1815188.765	700903.127	?	--		2042	4	29	1000NW Channel. ~30' lakeward of single sand bar. Perpendicular to shoreline, fuse pointed shoreward. On sand. ***Same orientation, buried 6".*** TRANSPONDER RANGE = 1 M
106	106-HE M344-1	A1	5/24/2002	10:30	~6.2'	41 35 21.04287	83 03 36.85537	1815245.333	700923.579	?	155.153	15	2119	5	30	1000 NW Channel. Shore parallel, fuse toward channel. On sand bottom. ***Same.*** PINGER RANGE = 0, BURIED
90	90-APT-2	A2 (north bank)	5/24/2002	10:45	~8'	41 35 13.59898	83 03 46.72818	1814490.270	700174.988	?	--		2041	3	28	River Area, North side. At S. edn of wood fence. Parallel to shore. Fuse lakeward. On mud bottom. ***Rolled down into river, buried ~1 ft.***
81	81-M43A1-1	A2 (south bank)	5/24/2002	11:45	4.5'	41 35 12.26301	83 03 47.10704	1814460.607	700039.955	?	--		2113	6	31	River Area, South side. Align wood fence on N. bank w/tree. Drogue perpendicular to river flow. On mud bottom. ***Same orientation.***
81	81-HE, M56-1	A3	9/20/2001	12:30	~3'	41 35 11.17401	83 03 25.80320	1816078.754	699919.324	?	155.113	11	2040	2	27	Placement Site. Parallel with channel center line. Fuse pointed lakeward. On sand bottom. ***No change.*** BURIED 4"-6". FUSE POINTED 140 DEG.
90	90-APR-1	A3	5/24/2002	12:50	~6'	41 35 11.59221	83 03 18.04920	1816668.243	699957.891	?	--		2114	7	32	Placement Site. Perpendicular to channel center line. Fuse pointing toward channel center line. On sand bottom. ***Buried 3", orientation unknown.*** PINGED
60	60-HE, M49A3-2	A4	5/24/2002		0						155.024	3	--	--	--	***Not Located.***
81	81-M43A1-2	A4	5/24/2002	12:55	~6'	41 35 08.56675	83 03 11.65336	1817152.311	699648.58	?	--		2039	1	25	1000SE Channel. Fuse pointed lakeward. On sand bottom. ***Fins toward shore, too deep to hold boad steady for visual.***

(Continued)

Table 7 (Concluded)

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	Deployment Notes = Normal font **Dec. 2001 Notes = Italic Bold** MAY 2002 NOTES = ALL CAPS
60	60-HE, M49A3-3	A5	5/24/2002	13:20	3.5'	41 34 57.07114	83 03 11.23694	1817176.362	698484.862	?	155.094	9	--	--	--	2500 SE Channel. On third sand bar lakeward from shore. Shore parallel. Fuse pointing toward Camp Perry. ***Rotated, fuse now toward river.***
90	90-APT-5	A5	5/24/2002	13:25	~6'	41 35 02.44274	83 03 01.70107	1817904.669	699023.953	?	--		2118	4	29	2500SE Channel. Shore Perpendicular. Fuse lakeward. On sand bottom. ***Hit drogue w/range pole but couldn't hold boat still enough to take fix.***
60	60-HE, M49A3-4	A6	5/25/2002	6:00	~3'	41 33 20.83576	83 01 40.55455	1824008.829	688701.754	?	155.054	4	--	--	--	Camp Perry Area. Water's edge. Fuse lakeward. On sand w/some gravel. ***75% buried.*** NO ATS RESPONSE AT RIPRAP SHORELINE
81	81-M43A1-3	A6	5/25/2002	6:10	~6.9'	41 33 23.33805	83 01 35.40167	1824402.106	688952.648	?	--		2115	1	25	Camp Perry Ara. Sandy bottom. Fuse lakeward. ***Too deep to locate.*** NO ATS RESPONSE AT RIPRAP SHORELINE
81	81-HE,M56-2	A6	5/25/2002	6:20	~5.4'	41 33 22.12495	83 01 38.06260	1824199.069	688831.09	?	155.012	1	2116	2	27	Camp Perry Area. Sandy/clay bottom. Fuse lakeward. ***Buried ~2".*** NO ATS RESPONSE AT RIPRAP SHORELINE
90	90-APT-4	A6	5/25/2002	6:30	~5.6'	41 33 22.05108	83 01 37.97143	1824205.954	688823.572	?	--		2117	3	28	Camp Perry Area. Sandy/clay bottom. Fuse lakeward. ***Buried ~.5".*** NO ATS RESPONSE AT RIPRAP SHORELINE
106	106-HE M344-2	A6	5/25/2002	6:40	~6.9'	41 33 23.25761	83 01 35.30142	1824409.678	688944.461	?	155.134	14	2043	5	30	Camp Perry Area. Sandy bottom. Fuse lakeward. ***Too deep to locate.*** NO ATS RESPONSE AT RIPRAP SHORELINE

Table 8
Transport of SO from Last Surveyed and Surveyed Locations During Survey No. 2

	SO Description		Mobility				Comments
Deployment Zone	**mm**	**Serial Number**	**Δ East (survey ft)**	**Δ North (survey ft)**	**Distance (survey ft) @ Azimuth (deg-True)**	**Δ Elevation (survey ft)**	Elevation on deployment was lake bed at drogue. Elevation Dec 2001 from top of drogue body.
A1	60	60-HE, M49A3-1					GONE. No response on ATS.
A1	90	90-APT-3	?	?	Within 1 m (3.28)	?	Buried, could not locate..
A1	106	106-HE M344-1	?	?	Within 1 m (3.28	?	Buried, could not locate.
A2 (north bank)	90	90-APT-2	?	?	Within 2.37 m (7.77)	?	Rolled down into river thalwag. Buried ~1 ft. Rotated 90°.
A2 (south bank)	81	81-M43A1-1	2.0163	7.0535	7.328@016°	?	Approx. half of drogue diameter exposed. Fins lakeward.
A3	81	81-HE, M56-1	0.5804	15.3839	15.467@002°	?	Buried 4”-6”. Fuse pointing 140°
A3	90	90-APT-1	?	?	Within 2.37 m (7.77)	?	Buried ,could not locate
A4	60	60-HE, M49A3-2					GONE. No response on ATS.
A4	81	81-HE, M43A1-2	?	?	Within 3.55 m (11.67)	?	Could not locate.
A5	60	60-HE, M49A3-3	?	?	In vicinity	?	Rcvd ATS signal. Could not locate.
A5	90	90-APT-5	?	~0	Within 3.55 m (11.67)	?	Could not locate
A6	60	60-HE, M49A3-4	?	?	?	?	No response.
A6	81	81-M43A1-3	?	?	?	?	No response.
A6	81	81-HE, M56-2	?	?	?	?	No response.
A6	90	90-APT-4	?	?	?	?	No response.
A6	106	106-HE M344-2	?	?	?	?	No response.

Survey No. 3, September 2002

The third post-deployment survey of SO positions took place on September 24-25, 2002 (approximately 1 year after deployment). During the survey, it was observed that some significant changes to the lake bed and shoreline had occurred. Immediately northwest of the mouth of the Toussaint River, where pieces of SO 60-1, 90-3, and 106-1 had been deployed, the shoreline had retreated approximately 30 ft, and the lakeward sandbars encountered on previous surveys no longer existed. Immediately southeast of the river, where pieces of SO 60-2 and 81M-2 had been deployed, an offshore sandbar was observed above the waterline.

Though not nearly as bad as during survey No. 2 in May, the water level was higher than what it was during the deployment, and there were waves coming from the northeast. These conditions made it difficult to survey 106-1, 90-5 and 60-4, and approximate distances from their last surveyed positions were acoustically measured using the same procedure employed during survey No. 2. SO 81M-3 and 106-2 could not be surveyed in the conditions encountered. The acoustic system was able to locate SO buried beneath the lake bed, and a portable airlift system was used to remove sediment from their locations so they could be visually identified. However, the poor water clarity, in combination with the additional turbidity caused by the airlift system, made visual observations difficult, even with the underwater video camera. The results of survey No. 3 are shown in Tables 9 and 10, which gives the transport of each piece of SO from its deployed and last surveyed location.

Table 9
Observations from Survey No. 3, September 2002

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic*
60	60-HE, M49A3-1	A1	9/20/2001		0						155.075	8	--	--	--	*Still gone. No response on ATS.*
90	90-APT-3	A1	9/24/2002	16:15	~4.5'	41 35 20.83676	83 03 37.59180	1815188.857	700902.898	567.443	--		2042	4	29	*Slightly buried.*
106	106-HE M344-1	A1	9/25/2002	9:15	~6.2'	41 35 21.04287	83 03 36.85537	1815245.333	700923.579	566.719	155.153	15	2119	5	30	*~1/4 of drogue exposed, oriented as deployed. Pinger & ATS responding.*
90	90-APT-2	A2 (north bank)	9/24/2002	15:45	~8'	41 35 13.59898	83 03 46.72818	1814490.270	700174.988	?	--		2041	3	28	*Pinger responding on location. Water too deep to acquire video or new position.*
81	81-M43A1-1	A2 (south bank)	9/24/2002	15:30	4.5'						--		2113	6	31	*No response from pinger. Drogue not located.*
81	81-HE, M56-1	A3	9/24/2002	12:05	~3'	41 35 11.01714	83 03 25.81252	1816077.570	699903.276	568.632	155.113	11	2040	2	27	*Fuse pointing 132 deg. Lying prode on bottom. Pinger & ATS responding.*
90	90-APR-1	A3	9/24/2002	13:02	~6'	41 35 11.58431	83 03 18.05907	1816667.115	699956.924	567.323	--		2114	7	32	*Dug 1.2' into lake bed, did not locate drogue. Pinger responding 1 m range.*
60	60-HE, M49A3-2	A4	9/20/2001		0						155.024	3	--	--	--	*Still gone. No response on ATS.*
81	81-M43A1-2	A4	9/24/2002	13:50	~6'	41 35 08.56675	83 03 11.65336	1817152.311	699648.58	566.206	--		2039	1	25	*Buried ~1". Fuse toward 276 deg.*

(Continued)

Table 9 (Concluded)

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
Mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic*
60	60-HE, M49A3-3	A5	9/24/2002	14:25	~2.5'	41 34 57.07114	83 03 11.23964	1817175.783	698485.036	569.075	155.094	9	--	--	--	*Buried ~1". Fuse toward river (NW).*
90	90-APT-5	A5	9/24/2002	14:50	~6'	41 35 02.44274	83 03 01.70107	1817904.669	699023.953	?	--		2118	4	29	*Pinger responding on location. Water too deep to acquire video or new position.*
60	60-HE, M49A3-4	A6	9/24/2002	7:30	~.5'	41 33 20.83576	83 01 40.55455	1824008.829	688701.754	?	155.054	4	--	--	--	*ATS responding at location. Dug extensively, yet did not locate.*
81	81-M43A1-3	A6	9/24/2002	8:00	~6'	41 33 23.33805	83 01 35.40167	1824402.106	688952.648	?	--		2115	1	25	*Pinger responding on location. Water too deep to acquire video or new position.*
81	81-HE,M56-2	A6	9/24/2002	8:24	~4'	41 33 22.12656	83 01 38.06178	1824198.859	688831.106	567.708	155.012	1	2116	2	27	*Buried 14" oriented shore-parallel.*
90	90-APT-4	A6	9/24/2002	8:33	~4'	41 33 22.05338	83 01 37.96864	1824205.894	688823.657	567.847	--		2117	3	28	*Buried 6" oriented shore-parallel.*
106	106-HE M344-2	A6	9/24/2002	8:00	~6'	41 33 23.25761	83 01 35.30142	1824409.678	688944.461	?	155.134	14	2043	5	30	*Pinger responding on location. Water too deep to acquire video or new position.*

Table 10
Transport of SO from Last Surveyed and Surveyed Locations During Survey No. 3

Deployment Zone	SO Description		Mobility Since Last Located		Mobility Since Deployment		Comments
	mm	Serial Number	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	
A1	60	60-HE, M49A3-1					GONE. No response on ATS.
A1	90	90-APT-3	.248@157°	0.503	.087@163°	0.21	Buried slightly
A1	106	106-HE M344-1	0	?	1.501@265°	-0.224	Approx. 1/4 of drogue diameter exposed. Fuse toward river.
A2 (north bank)	90	90-APT-2	Within 1 m (3.28)	?	?	?	Previously rolled down into river thalwag. Buried ~1 ft.
A2 (south bank)	81	81-M43A1-1	?	?	7.328@016°	?	GONE. No response on pinger.
A3	81	81-HE, M56-1	16.092@184°	?	.893@234°	0.136	Lying proud. Fuse pointing 132°. May 2002 position highly suspect.
A3	90	90-APT-1	.04@085°	-0.705	.346@354°	-0.7	Buried ,could not precisely locate
A4	60	60-HE, M49A3-2					GONE. No response on ATS.
A4	81	81-HE, M43A1-2	.712@104°	-0.679	.599@035°	-0.5	Buried 1”, fuse at 276°.
A5	60	60-HE, M49A3-3	.605@287	?	.663@277°	-0.94	Buried 1’, fuse at 300°.
A5	90	90-APT-5	Within 1 m (3.28)	?	Within 1 m (3.28)	?	Could not locate. Water too deep.
A6	60	60-HE, M49A3-4	Within 1 m (3.28)	?	Within 1 m (3.28)	-0.905	ATS responding well but did not locate by digging.
A6	81	81-M43A1-3	?	?	?	?	Water too deep to locate drogue.
A6	81	81-HE, M56-2	.211@274	0.671	.744@209	-0.011	Buried 14” oriented shore-parallel.
A6	90	90-APT-4	.104@324	0.049	.479@208	0.034	Buried 6” oriented shore-parallel.
A6	106	106-HE M344-2	?	?	?	?	Water too deep to locate drogue.

Ice SO Deployment, February 2003

SO were deployed to investigate their possible migration as a result of being frozen in the ice at the ice/sediment interface (see Figure 27) and transported by ice movement, and/or by being "pushed" by a drifting ice floe .The field operation on February 8-10, 2003 was conducted primarily to deploy new SO, then survey previously placed SO if time permitted. The site-specific health and safety plan was modified for this ice operation. All safety issues were addressed, and contingencies were in place for any anticipated ice hazard scenario. Safety meetings, coordination, and proper outfitting of all personnel preceded each excursion onto the ice. The eight new pieces of SO were placed on the lake bed by cutting through the ice with an auger and/or chain saw (Figure 28).

The deployment of the newly manufactured SO commenced on February 9, 2003. New deployment zones, referred to as area 7 and area 8, were selected to provide a more continuous coverage along the FUDS beach (at the request of the Buffalo District). These new areas were located between existing areas 5 and 6 (Figure 29). The deployment location of each new SO within areas 7 and 8 was assessed by auguring an exploration hole to determine ice thickness and depth of unfrozen water underneath the ice (or if water was completely frozen to determine ice thickness to the ice/sediment interface). One of each of the four SO types was placed in both area 7 and area 8. The procedure for the deployment was as follows:

a. Site selection

b. Anomaly avoidance check

c. Auger and/or chainsaw through the ice and confirm site selection

d. Break up and remove ice pieces

e. Place the new SO on the lake bed

f. Acquire RTK-DGPS position and note orientation

g. Fill ice hole with water and/or ice

Examples of various placement conditions are shown in Figures 30, 31, 32, and 33 . The eight newly deployed SO were 60-5 and -6, 81M-4 and -5, 81H-3 and -4, and 106-3 and -4. Identification details regarding these SO are given in Tables 3 and 11, and the deployment locations are shown in Figure 29. The study area was covered in continuous ice, which varied from 7 to 26 in. thick.

Two pieces of SO, 81M-3 and 106-2, that had not been relocated since deployment (September, 2001) were located by cutting through the ice at the deployment location, followed by probing the bottom with a pole. Tables 12 and 13 present observations from the ice deployment operation.

Figure 27. Example of frozen sediment/lake ice interface retrieved during February SO deployment

Figure 28. Cutting hole in ice to deploy SO

Table 11
Eight New SO Deployed February 2003

Type	Serial No.	Quantity
60-mm M49A3	5,6	2
81-mmM43A1	4,5	2
81-mm HE M56	3,4	2
106-mm HE M344	3,4	2

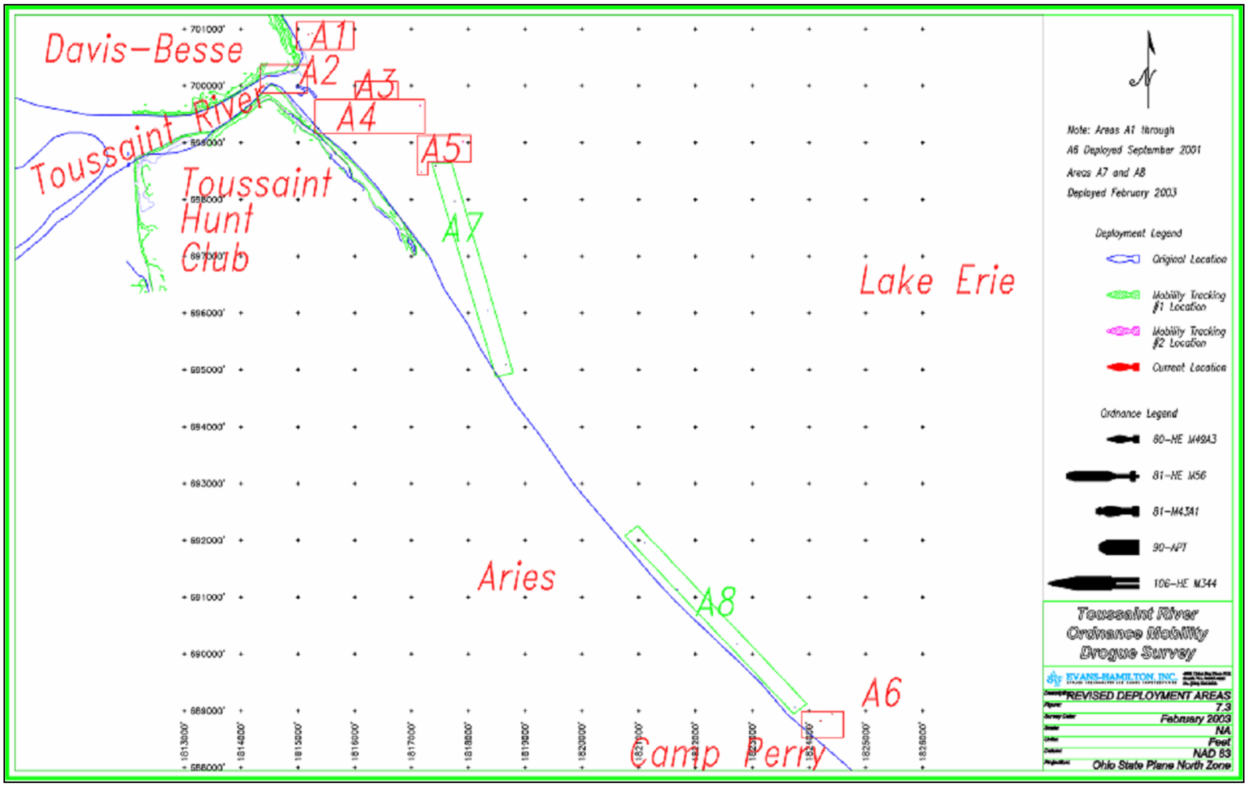


Figure 29. Locations of all SO deployed in study

Figure 30. 60-5 placed at ice/sediment interface in 7-in.-thick ice

Figure 31. 81H-3 place under 23-in.-thick ice

Figure 32. Surveying 81M-5 deployed at ice/sediment interface in 8-in.-thick ice

Figure 33. 106-3 deployed under 12-in.-thick ice

Table 12
Observations from Ice Deployment, February 2003

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number (Fine Tune)	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic* Feb 2003 Notes - Normal
60	60-HE, M49A3-1	A1	9/20/2001		0						155.075	8 (FT @ 1 or 2)	--	--	--	*Still gone. No response on ATS.*
90	90-APT-3	A1	9/24/2002	16:15	~4.5'	41 35 20.83676	83 03 37.59180	1815188.857	700902.898	567.443	--		2042	4	29	*Slightly buried.*
106	106-HE M344-1	A1	9/25/2002	9:15	~6.2'	41 35 21.04287	83 03 36.85537	1815245.333	700923.579	566.719	155.153	15 (FT @ 8 or 9)	2119	5	30	*~1/4 of drogue exposed, oriented as deployed. Pinger & ATS responding.*
90	90-APT-2	A2 (north bank)	9/24/2002	15:45	~8'	41 35 13.59898	83 03 46.72818	1814490.270	700174.988	?	--		2041	3	28	*Pinger responding on location. Water too deep to acquire video or new position.*
81	81-M43A1-1	A2 (south bank)	9/24/2002	15:30	4.5'						--		2113	6	31	*No response from pinger. Drogue not located.*
81	81-HE, M56-1	A3	9/24/2002	12:05	~3'	41 35 11.01714	83 03 25.81252	1816077.570	699903.276	568.632	155.113	11 (FT @ 7 or 8)	2040	2	27	*Fuse pointing 132 deg. Lying prode on bottom. Pinger & ATS responding.*
90	90-APR-1	A3	9/24/2002	13:02	~6'	41 35 11.58431	83 03 18.05907	1816667.115	699956.924	567.323	--		2114	7	32	*Dug 1.2' into lake bed, did not locate drogue. Pinger responding 1 m range.*
60	60-HE, M49A3-2	A4	9/20/2001		0						155.024	2 (FT @ 8 or 9)	--	--	--	*Still gone. No response on ATS.*
81	81-M43A1-2	A4	9/24/2002	13:50	~6'	41 35 08.56675	83 03 11.65336	1817152.311	699648.58	566.206	--		2039	1	25	*Buried ~1". Fuse toward 276 deg.*
60	60-HE, M49A3-3	A5	9/24/2002	14:25	~2.5'	41 34 57.07114	83 03 11.23964	1817175.783	698485.036	569.075	155.094	9 (FT @ 8 or 9)	--	--	--	*Buried ~1". Fuse toward river (NW).*
90	90-APT-5	A5	9/24/2002	14:50	~6'	41 35 02.44274	83 03 01.70107	1817904.669	699023.953	?	--		2118	4	29	*Pinger responding on location. Water too deep to acquire video or new position.*
60	60-HE, M49A3-4	A6	9/24/2002	7:30	~.5'	41 33 20.83576	83 01 40.55455	1824008.829	688701.754	?	155.054	5 (FT @ 8 or 9)	--	--	--	*ATS responding at location. Dug extensively, yet did not locate.*
81	81-M43A1-3	A6	2/9/2003	16:03	~1' ICE	41 33 23.33538	83 01 35.40285	1824401.741	688952.234	566.301	--		2115	1	25	Augered & chain sawed throu ice at location. Located with prod.
81	81-HE,M56-2	A6	9/24/2002	8:24	~4'	41 33 22.12656	83 01 38.06178	1824198.859	688831.106	567.708	155.012	1 (FT @ 8 or 9)	2116	2	27	*Buried 14" oriented shore-parallel.*
90	90-APT-4	A6	9/24/2002	8:33	~4'	41 33 22.05338	83 01 37.96864	1824205.894	688823.657	567.847	--		2117	3	28	*Buried 6" oriented shore-parallel.*
106	106-HE M344-2	A6	2/9/3003	16:04	~1' ICE	41 33 23.25800	83 01 35.29949	1824409.551	688944.355	566.091	155.134	13 (FT @ 8 or 9)	2043	5	30	Augered & chain sawed throu ice at location. Located with prod.

(Continued)

Table 12 (Concluded)

SO Description		Deployment Zone	Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
Mm	Serial Number		Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number (Fine Tune)	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic* Feb 2003 Notes - Normal
60	60-HE, M49A3-5	A7	2/9/2003	13:05	7" ICE	41 34 33.03473	83 02 55.71779	1818340.258	696044.412	570.11	155.122	12 (FT @ 8 or 9)	--	--	--	Placed on top of sand. Fuse lakeward.
81	81-M43A1-4	A7	2/9/2003	11:33	8" ICE	41 34 58.17794	83 03 08.07064	1817417.535	698595.189	569.996	--	--	2375	7	32	Placed on top of sand. Fuse pointing north.
81	81-HE,M56-3	A7	2/9/2003	13:55	23" ICE	41 34 23.60624	83 02 51.31713	1818668.724	695088.014	568.354	155.044	4 (FT @ 8 or 9)	2376	2	27	Placed on top of sand, between two sand bars. Ice all the way to the sand. Fuse lakeward.
106	106-HE ME44-3	A7	2/9/2003	12:20	12" ICE	41 34 51.95648	83 03 03.57687	1817755.055	697963.328	569.182	155.104	10 (FT @ 8 or 9)	2374	1	25	Placed on top of sand on lakeward side of sandbar. Fuse pointing south.
60	60-HE, M49A3-6	A8	2/9/2003	16:05	8" ICE	41 33 44.77200	83 02 11.39767	1821678.611	691138.591	569.937	155.084	10	--	--	--	Placed on top of sand. Ice all the way to the sand. Fuse lakeward.
81	81-M43A1-5	A8	2/9/2003	15:27	36" ICE	41 33 52.85958	83 02 19.08826	1821099.049	691960.769	568.782	--	--	2379	6	31	Placed on top of sand. Ice all the way to the sand. Fuse lakeward.
81	81-HE,M56-4	A8	2/10/2003	13:05	23" ICE	41 33 35.31068	83 01 57.39652	1822737.092	690174.451	568.772	155.064	6 (FT @ 8 or 9)	2377	7	32	Placed on top of sand. Ice all the way to the sand. Fuse raised ~1" above sand on piece of ice. Fuse pointed north.
106	106-HE ME44-4	A8	2/10/2003	12:35	18" ICE	41 33 24.41319	83 01 44.04681	1823745.252	689065.3	569.547	155.034	3 (FT @ 8 or 9)	2378	4	29	Placed on top of sand. Ice all the way to the sand. Fuse pointing south.

Table 13
Transport of SO from Last Surveyed and Surveyed Locations During Ice Deployment Survey February 2003

Deployment Zone	SO Description		Mobility Since Last Located		Mobility Since Deployment		Comments
	mm	Serial Number	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	Sept 2002 Notes = Italic Feb 2003 Notes - Normal
A1	60	60-HE, M49A3-1					*GONE. No response on ATS.* Not attempted this trip
A1	90	90-APT-3	.248@157°	0.503	.087@163°	0.21	*Buried slightly.* Not attempted this trip.
A1	106	106-HE M344-1	0	?	1.501@265°	-0.224	*Approx. 1/4 of drogue diameter exposed. Fuse toward river.* Not attempted this trip.
A2 (north bank)	90	90-APT-2	Within 1 m (3.28)	?	?	?	*Previously rolled down into river thalwag. Buried ~1 ft.* Not attempted this trip
A2 (south bank)	81	81-M43A1-1	?	?	7.328@016°	?	*GONE. No response on pinger.* Not attempted this trip.
A3	81	81-HE, M56-1	16.092@184°	?	.893@234°	0.136	*Lying proud. Fuse pointing 132°. May 2002 position highly suspect.* Not attempted this trip.
A3	90	90-APT-1	.04@085°	-0.705	.346@354°	-0.7	*Buried ,could not precisely locate.* Not attempted this trip.
A4	60	60-HE, M49A3-2					*GONE. No response on ATS.* Not attempted this trip.
A4	81	81-HE, M43A1-2	.712@104°	-0.679	.599@035°	-0.5	*Buried 1", fuse at 276°.* Not attempted this trip
A5	60	60-HE, M49A3-3	.605@287	?	.663@277°	-0.94	*Buried 1', fuse at 300°.* Not attempted this trip.
A5	90	90-APT-5	Within 1 m (3.28)	?	Within 1 m (3.28)	?	*Could not locate. Water too deep.* Not attempted this trip.
A6	60	60-HE, M49A3-4	Within 1 m (3.28)	?	Within 1 m (3.28)	-0.905	*ATS responding well but did not locate by digging.* Not attempted this trip
A6	81	81-M43A1-3	NA	NA	.552@221	-0.316	*Water too deep to locate drogue.* Not attempted this trip
A6	81	81-HE, M56-2	.211@274	0.671	.744@209	-0.011	*Buried 14" oriented shore-parallel.* Not attempted this trip
A6	90	90-APT-4	.104@324	0.049	.479@208	0.034	*Buried 6" oriented shore-parallel.* Not attempted this trip
A6	106	106-HE M344-2	NA	NA	.165@230	0.667	Located with brpbe only. Could not get camera through ice.

(Continued)

Table 13 (Concluded)

Deployment Zone	SO Description		Mobility Since Last Located		Mobility Since Deployment		Comments
	mm	**Serial Number**	**Distance (survey ft) @ Azimuth (deg-True)**	**Δ Elevation (survey ft)**	**Distance (survey ft) @ Azimuth (deg-True)**	**Δ Elevation (survey ft)**	Sept 2002 Notes = Italic Feb 2003 Notes - Normal
A7	60	60-HE, M49A3-5	NA	NA	NA	NA	Deployed this trip.
A7	81	81-M43A1-4	NA	NA	NA	NA	Deployed this trip.
A7	81	81-HE, M56-3	NA	NA	NA	NA	Deployed this trip.
A7	106	106-HE M344-3	NA	NA	NA	NA	Deployed this trip.
A8	60	60-HE, M49A3-6	NA	NA	NA	NA	Deployed this trip.
A8	81	81-M43A1-5	NA	NA	NA	NA	Deployed this trip.
A8	81	81-HE, M56-4	NA	NA	NA	NA	Deployed this trip.
A8	106	106-HE M344-4	NA	NA	NA	NA	Deployed this trip.

Final Survey and Recovery, July 2003

The final survey of SO positions and recovery of the SO took place on July 15-17, 2003. This time period was chosen by ERDC, to accommodate schedules of several groups, particularly the schedule of the anomaly avoidance/safety officer, and Navy EOD divers (EODMU-2 Detachment Crane, Indiana). The divers were particularly important for recovery of the drogues in the deeper water sections as illustrated in Figure 34. The diver was equipped with an electromagnetic metal detector to identify anomalies (actual ordnance) and locate buried SO that remained near the last known coordinates. Acoustic and radio tracking systems were used to find SO that had migrated significant distances away from their last known coordinates. After an SO was located, the diver would dig down to the item if it was buried, locate the SO midsection, hold the survey rod point until a fix was obtained, identify residence aspects (orientation, depth of burial, etc.), then recover the item. Examples of the SO recovery conditions are presented in Figures 35 and 36 (note zebra mussels on Figure 36).

Figure 34. Navy EOD diver recovering SO

Figure 35. Recovered 81 M SO

Figure 36. Recovered 106-1 SO

The final surveyed positions are given in Table 14. A national pistol competition was taking place at Camp Perry during this period. The competition impacted the field operations, and eventually resulted in abandonment of the recovery of SO 81M-3 and 106-2. The final net movement of most of the SO from their deployment locations was less than 1.6 ft (Table 15). Two pieces of SO, 106-1 and 81H-2, moved in a shoreward direction 6.4 and 5.6 ft, respectively. One piece of SO that was placed in the ice in February (81M-4) moved approximately 50 ft, also in a shoreward direction. Two pieces of SO discovered missing on the first survey, 60-1 and 60-2, were not located by the divers, and an additional piece, 90-2, was not found.

Table 14
Observations from SO Recovery July 2003

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number (Fine Tune)	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic* Feb 2003 Notes – Normal **Recovery July 2003 - Bold**
60	60-HE, M49A3-1	A1	9/20/2001		0						155.075	8 (FT @ 1 or 2)	--	--	--	*Still gone. No response on ATS.* **Still gone.**
90	90-APT-3	A1	7/16/2003	11:43	~4.5'	41 35 20.84326	83 03 37.59892	1815188.315	700902.655	Non kinemaic	--		2042	4	29	*Slightly buried.* **Standing proud.**
106	106-HE M344-1	A1	7/15/2003	16:15	~6.2'	41 35 21.046933	83 03 36.90884	1815240.903	700926.104	566.719	155.153	15 (FT @ 8 or 9)	2119	5	30	*~1/4 of drogue exposed, oriented as deployed. Pinger & ATS responding.* **Half buried.**
90	90-APT-2	A2 (north bank)	9/24/2002	15:45	~8'	41 35 13.59898	83 03 46.72818	1814490.270	700174.988	?	--		2041	3	28	*Pinger responding on location. Water too deep to acquire video or new position.* **Not recovered by diver search. No pinger response.**
81	81-M43A1-1	A2 (south bank)	7/15/2003	15:46	4.5'	41 35 12.20401	83 03 47.13704	181445.910	700033.811	?	--		2113	6	31	*No response from pinger. Drogue not located.* **Located w/diver's metal detector. Buried 4".**
81	81-HE, M56-1	A3	7/16/2003	10.42	~3'	41 35 11.01593	83 03 25.81173	1816077.629	699903.153	568.144	155.113	11 (FT @ 7 or 8)	2040	2	27	*Fuse pointing 132°. Lying prode on bottom. Pinger & ATS responding.* **Buried 3".**
90	90-APR-1	A3	7/17/2003	11:39	~6'	41 35 11.59969	83 03 18.05351	1816667.548	699958.478	566.78	--		2114	7	32	*Dug 1.2' into lake bed, did not locate drogue. Pinger responding 1 m range.* **Buried 8".**
60	60-HE, M49A3-2	A4	9/20/2001		0						155.024	2 (FT @ 8 or 9)	--	--	--	*Still gone. No response on ATS.* **Still gone.**
81	81-M43A1-2	A4	9/24/2002	13:50	~6'	41 35 08.56675	83 03 11.65336	1817152.311	699648.58	566.9	--		2039	1	25	*Buried ~1". Fuse toward 276°.* **Buried 8". Fuse lakeward.**
60	60-HE, M49A3-3	A5	7/16/2003	12:41	~2.5'	41 34 57.07540	83 03 11.23332	1817176.485	698485.119	569.349	155.094	9 (FT @ 8 or 9)	--	--	--	*Buried ~1". Fuse toward river (NW).* **Buried 6".**
90	90-APT-5	A5	7/17/2003	10:27	~6'	41 35 02.45523	83 03 01.70508	1817904.009	699025.054	565.34	--		2118	4	29	*Pinger responding on location. Water too deep to acquire video or new position.* **Buried 4".**

(Continued)

Table 14 (Concluded)

SO Description			Deployed Locations (WGS 84/NAD 83)								ATS Transmitter		Datasonics Pinger			Comments
Mm	Serial Number	Deployment Zone	Date	Time (local)	Water Depth (ft) rel to surface	Latitude (°N)	Longitude (°W)	State Plane (Easting-survey ft)	State Plane (Northing-survey ft)	Elevation (survey ft)	Serial Number (kHz)	ATS Channel Number (Fine Tune)	Serial Number	Channel Number	Frequency (kHz)	*Sept 2002 Notes = Italic* Feb 2003 Notes – Normal **Recovery July 2003 - Bold**
60	60-HE, M49A3-4	A6	7/16/2003	19:35	~.5'	41 33 20.84910	83 01 40.55496	1824009.217	688702.952	569.521	155.054	5 (FT @ 8 or 9)	--	--	--	*ATS responding at location. Dug extensively, yet did not locate.* **Buried 8".**
81	81-M43A1-3	A6	2/9/2003	16:03	~1' ICE	41 33 23.33538	83 01 35.40285	1824401.741	688952.234	566.301	--		2115	1	25	Augered & chainsawed through ice at location. Located with prod. **Not recovered due to Camp Perry firing schedule.**
81	81-HE,M56-2	A6	7/16/2003	19:23	~4'	41 33 22.10093	83 01 38.11755	1824194.603	688828.538	567.403	155.012	1 (FT @ 8 or 9)	2116	2	27	*Buried 14" oriented shore-parallel.* **Buried 18".**
90	90-APT-4	A6	7/16/2003	18:59	~4'	41 33 22.05525	83 01 37.96838	1824205.915	688823.8467	567.584	--		2117	3	28	*Buried 6" oriented shore-parallel.* **Buried 16".**
106	106-HE M344-2	A6	2/9/3003	16:04	~1' ICE	41 33 23.25800	83 01 35.29949	1824409.551	688944.355	566.091	155.134	13 (FT @ 8 or 9)	2043	5	30	Augered & chainsawed through ice at location. Located with prod. **Not recovered due to Camp Perry firing schedule.**
60	60-HE, M49A3-5	A7	7/16/2003	14:55	?	41 34 33.0416	83 02 55.75784	1818337.222	696045.791	569.536	155.122	12 (FT @ 8 or 9)	--	--	--	Placed on top of sand. Fuse lakeward. **Buried 8". Fuse lakeward.**
81	81-M43A1-4	A7	7/16/2003	13:30	?	41 34 57.89419	83 03 08.60789	1817376.526	698566.728	567.418	--	--	2375	7	32	Placed on top of sand. Fuse pointing north. **Buried 6". Fuse pointing 300°.**
81	81-HE,M56-3	A7	7/16/2003	15:41	?	41 34 23.61864	83 02 51.31539	1818668.863	695089.268	567.858	155.044	4 (FT @ 8 or 9)	2376	2	27	Placed on top of sand, between two sand bars. Ice all the way to the sand. Fuse lakeward. **Half-buried. Fuse pointing 120°.**
106	106-HE ME44-3	A7	7/16/2003	14:19	?	41 34 51.95008	83 03 03.58539	1817754.403	697962.684	568.028	155.104	10 (FT @ 8 or 9)	2374	1	25	Placed on top of sand on lakeward side of sandbar. Fuse pointing south. **Buried 16". Fuse pointing 120°.**
60	60-HE, M49A3-6	A8	7/16/2003	17:25	?	41 33 44.77121	83 02 11.39843	1821678.553	691138.51	569.322	155.084	10	--	--	--	Placed on top of sand. Ice all the way to the sand. Fuse lakeward. **Buried 6". Fuse lakeward**
81	81-M43A1-5	A8	7/16/2003	16:29	?	41 33 52.85137	83 02 19.07910	1821099.74	691959.933	567.712	--	--	2379	6	31	Placed on top of sand. Ice all the way to the sand. Fuse lakeward. **Not buried. Fuse lakeward.**
81	81-HE,M56-4	A8	7/16/2003	17:51	?	41 33 35.30998	83 01 57.40081	1822736.765	690174.382	568.042	155.064	6 (FT @ 8 or 9)	2377	7	32	Placed on top of sand. Ice all the way to the sand. Fuse raised ~1" above sand on piece of ice. Fuse pointed north. **No diver report.**
106	106-HE ME44-4	A8	7/16/2003	18:31	?	41 33 24.41098	83 01 44.04632	1823745.288	689065.075	568.961	155.034	3 (FT @ 8 or 9)	2378	4	29	Placed on top of sand. Ice all the way to the sand. Fuse pointing south. **Buried 6".**

Table 15
Transport of SO from Last Surveyed and Surveyed Locations During Recovery Survey

	SO Description		Mobility Since Last Located		Mobility Since Deployment		Comments
Deployment Zone	**mm**	**Serial Number**	**Distance (survey ft) @ Azimuth (deg-True)**	**Δ Elevation (survey ft)**	**Distance (survey ft) @ Azimuth (deg-True)**	**Δ Elevation (survey ft)**	Sept 2002 Notes = Italic Feb 2003 Notes - Normal **July 2003 Notes - Bold**
A1	60	60-HE, M49A3-1					*GONE. No response on ATS.* Not attempted this trip. **Still gone.**
A1	90	90-APT-3	.595@246°	-0.410	.0612@238°	0.410	*Buried slightly*. Not attempted this trip. **Standing proud.**
A1	106	106-HE M344-1	5.099@346°	?	6.39@292°	-0.224	*Approx. 1/4 of drogue diameter exposed. Fuse toward river*. Not attempted this trip. **Half buried.**
A2 (north bank)	90	90-APT-2	?	?	?	?	*Previously rolled down into river thalwag. Buried ~1 ft.* Not attempted this trip. **No Com, not found after diver search.**
A2 (south bank)	81	81-M43A1-1	?	?	1.347@338°	?	*GONE. No response on pinger.* Not attempted this trip. **Located w/diver's metal detector. Buried 4".**
A3	81	81-HE, M56-1	0.136@154°	-0.488	0.925@226°	-0.824	*Lying proud. Fuse pointing 132°. May 2002 position highly suspect.* Not attempted this trip. **Buried 3".**
A3	90	90-APT-1	.939@308°	0.687	1.207@320°	0.189	*Buried ,could not precisely locate.* Not attempted this trip. **Buried 8".**
A4	60	60-HE, M49A3-2					*GONE. No response on ATS.* Not attempted this trip. **Still gone.**
A4	81	81-HE, M43A1-2	1.035@282°	0.7	1.621@302°	0.2	*Buried 1", fuse at 276°.* Not attempted this trip. **Tail 8" below.**
A5	60	60-HE, M49A3-3	.707@087	?	.171@018°	-0.666	*Buried 1', fuse at 300°.* Not attempted this trip. **Buried 6".**
A5	90	90-APT-5	Within 1 m (3.28)	?	1.284@329°	-0.579	*Could not locate. Water too deep.* Not attempted this trip. **Buried 4".**

(Continued)

Table 15 (Concluded)

Deployment Zone	SO Description		Mobility Since Last Located		Mobility Since Deployment		Comments
	mm	Serial Number	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	Distance (survey ft) @ Azimuth (deg-True)	Δ Elevation (survey ft)	*Sept 2002 Notes = Italic* Feb 2003 Notes - Normal **July 2003 Notes - Bold**
A6	60	60-HE, M49A3-4	Within 1 m (3.28)	?	1.473@018°	-0.795	*ATS responding well but did not locate by digging.* Not attempted this trip. **Buried 8".**
A6	81	81-M43A1-3	?	?	?	?	*Water too deep to locate drogue.* Not attempted this trip. **Not recovered due to Camp Perry firing schedule.**
A6	81	81-HE, M56-2	4.971@239	-0.1	5.629@235°	-0.494	*Buried 14" oriented shore-parallel.* Not attempted this trip. **Buried 18".**
A6	90	90-APT-4	.191@006	-0.058	0.31@221°	-0.297	*Buried 6" oriented shore-parallel.* Not attempted this trip. **Buried 16".**
A6	106	106-HE M344-2	?	?	?	?	Located with brpbe only. Could not get camera through ice. **Not recovered due to Camp Perry firing schedule.**
A7	60	60-HE, M49A3-5	NA	NA	3.334@294°	-0.574	Deployed this trip. **Buried 8". Fuse lakeward.**
A7	81	81-M43A1-4	NA	NA	49.919@235°	-2.578	Deployed this trip. **Buried 6". Fuse lakeward.**
A7	81	81-HE, M56-3	NA	NA	1.262@006°	-0.496	Deployed this trip. **Half buried. Fuse pointing 120°.**
A7	106	106-HE M344-3	NA	NA	0.916@225°	-1.154	Deployed this trip. **Half buried. Fuse pointing 120°.**
A8	60	60-HE, M49A3-6	NA	NA	0.099@216°	-0.615	Deployed this trip. **Buried 6". Fuse lakeward.**
A8	81	81-M43A1-5	NA	NA	1.084@140°	-1.07	Deployed this trip. **Not buried. Fuse lakeward.**
A8	81	81-HE, M56-4	NA	NA	0.334@258°	-0.73	Deployed this trip. **No diver report.**
A8	106	106-HE M344-4	NA	NA	0.227@171°	-0.586	Deployed this trip. **Buried 6".**

5 Ice, Water Level, and Wave Conditions

Two sources of ice information for Lake Erie are available. The National Oceanic and Atmospheric Administration's (NOAA) National Ice Center (NIC) (http://www.natice.noaa.gov/) and Environment Canada's Canadian Ice Service (http://ice-glaces.ec.gc.ca/) maintain Web site pages that present Great Lakes ice charts. Both contain information on the amount and thickness of ice on Lake Erie, and on ice flow size. Tables of ice coverage data near the Toussaint River, taken from these two sources are given in Appendix B. Graphical representations of the data are shown in Figures 37 through 40.

Available historical ice conditions were summarized to assess the severity of the winters of 2001-2002 and 2002-2003. Unfortunately, detailed ice information is not available before 1995 from either the Canadian Ice Service (CIS) or National Ice Center (NIC). The only information available is digital ice charts from NOAA's Great Lakes Environmental Research Laboratory (GLERL) from 1973 to 2000 (Norton et al. 2000). These charts only give the percentage of ice cover on the Great Lakes and do not discuss thickness or size. Percent ice cover taken from CIS, NIC, and GLERL data were compared for the period 1998-2000. The GLERL data correlated well with the other two sources, suggesting that the entire data set (1973-2000) may be used as a basis of comparison to assess the ice severity during the field study.

Table 16 presents the average ice cover from 1973 to 2000 for the western portion of Lake Erie near the Toussaint River. At this location, the lake is covered by 0 percent to 30 percent ice, for 49.8 percent of the winter. For 5.3 percent of the winter, it is covered by 30 percent to 80 percent ice, and for 44.9 percent of the winter, 80 percent to 100 percent ice cover is present. Ice cover greater than 10 percent generally begins between mid-December and early January, and ends late February to mid-March. The earliest record of ice cover above 10 percent was December 11, and the latest ice cover remained was April 12. The average amount of time during the winter with ice coverage above 10 percent was 67 days, with the maximum and minimum of time being 114 days and 0 days, respectively.

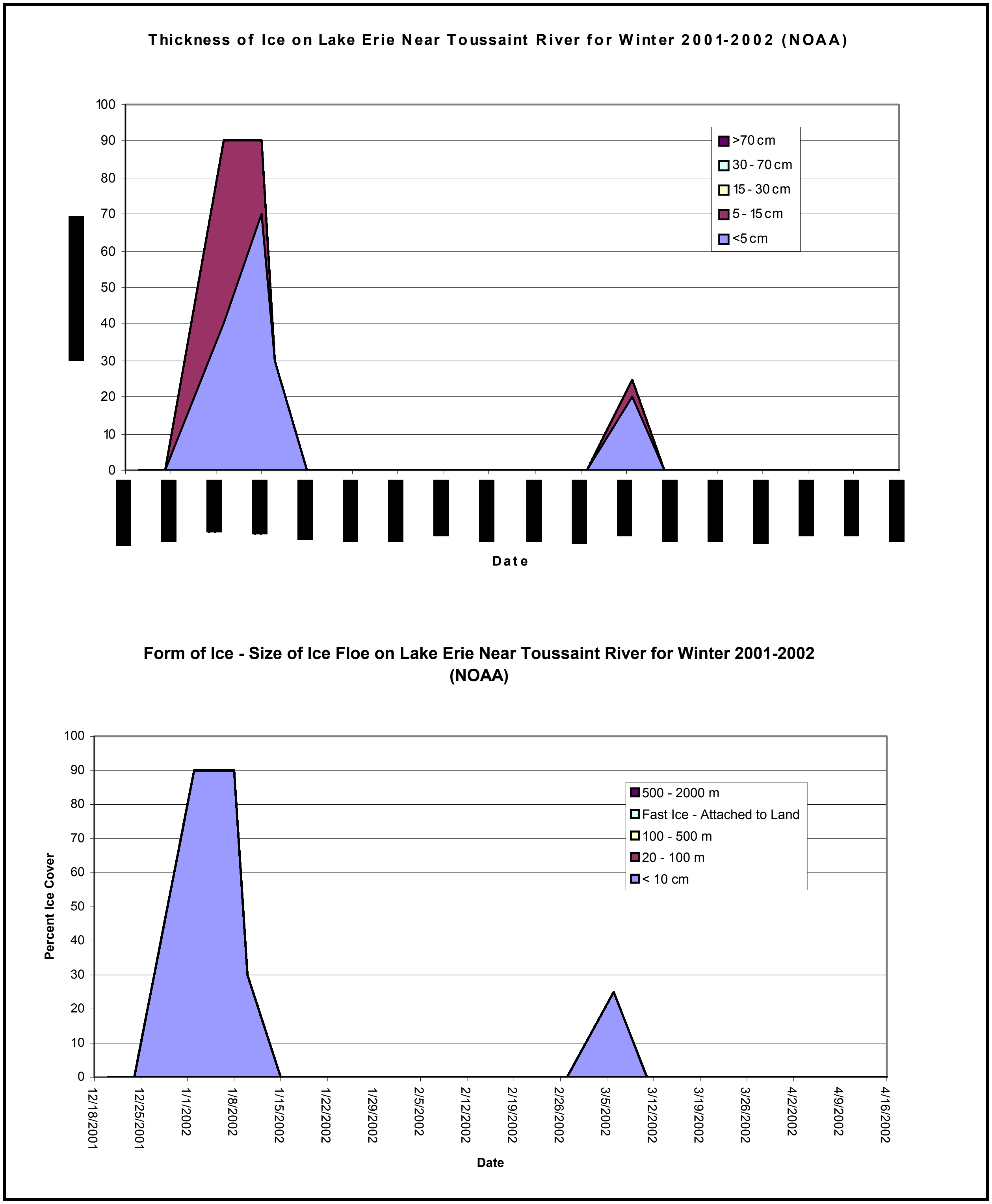


Figure 37. Ice thickness and ice floe size for winter 2001-2002 (NOAA)

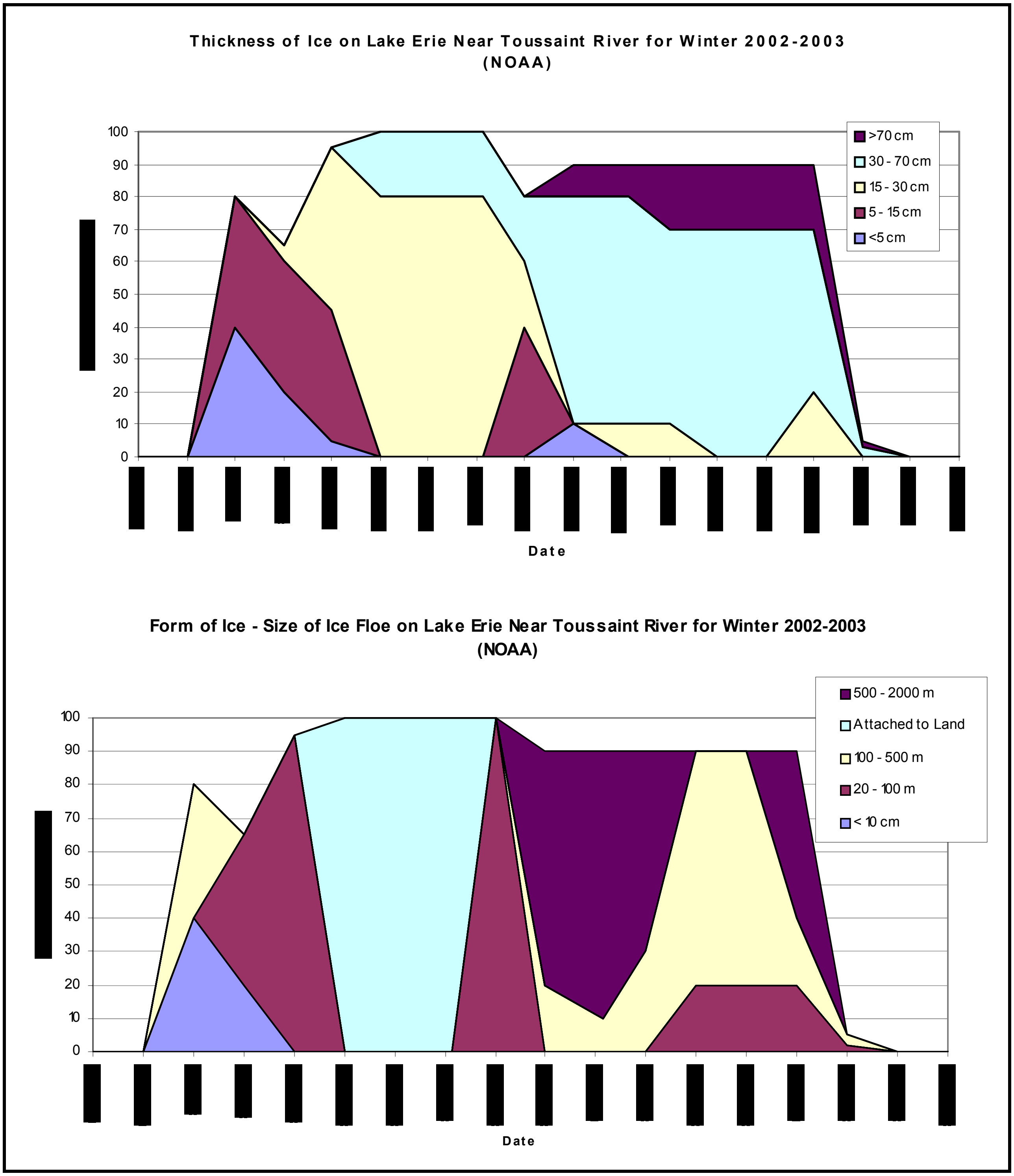


Figure 38. Ice thickness and ice floe size for winter 2002-2003 (NOAA)

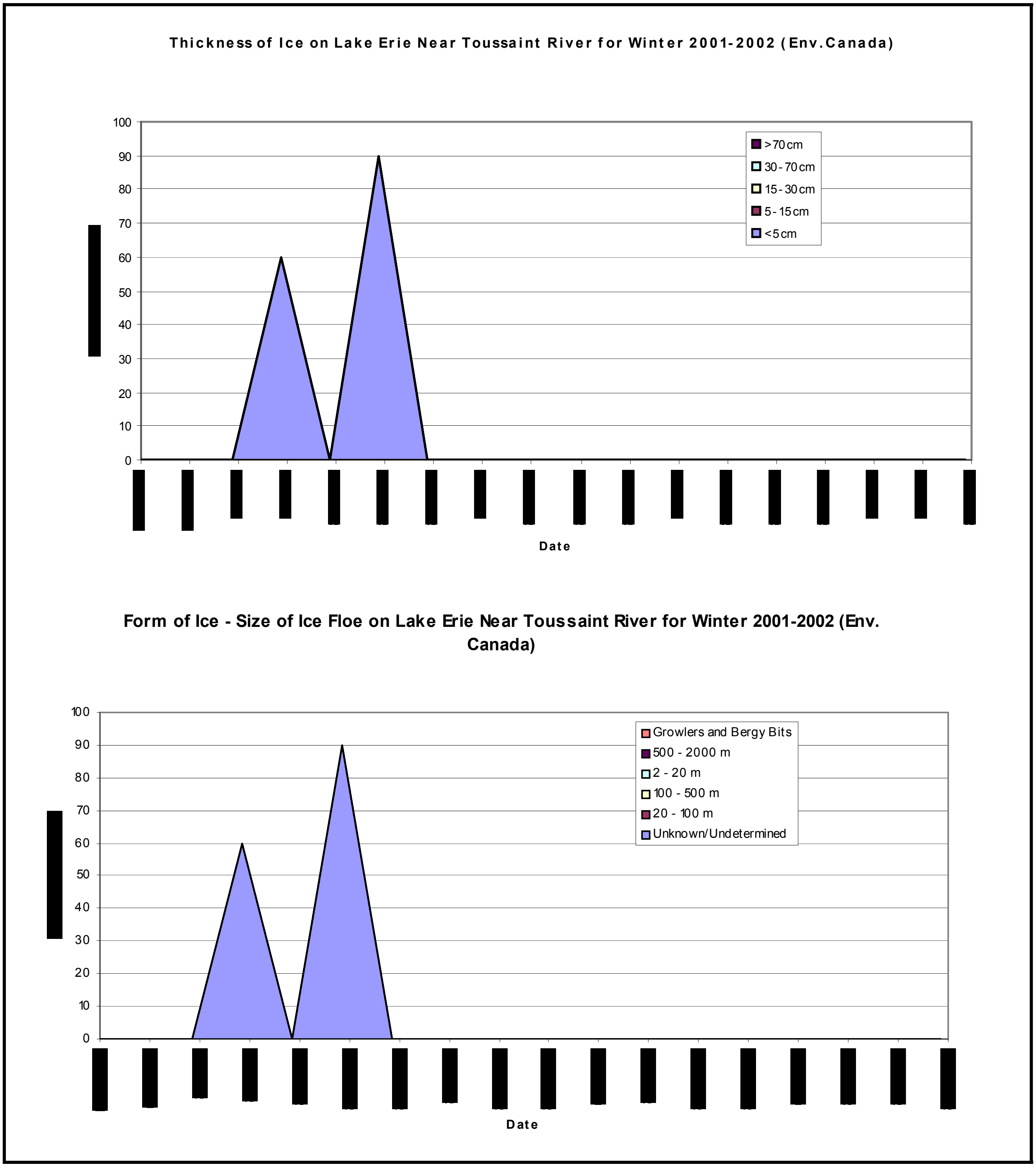


Figure 39. Ice thickness and ice floe size for winter 2001-2002 (Environment Canada)

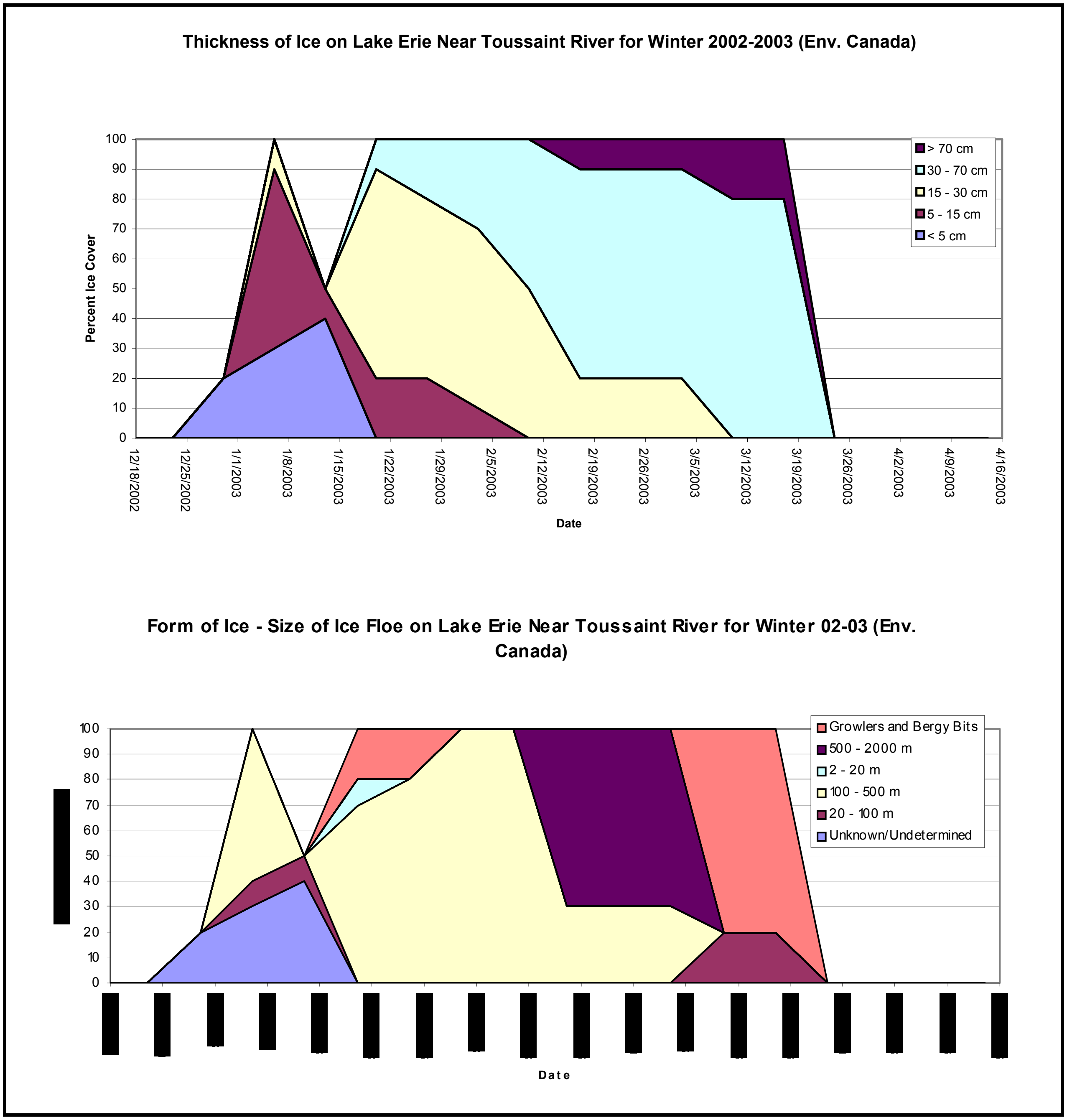


Figure 40. Ice thickness and ice flow size for winter 2002-2003 (Environment Canada)

Table 16
Average Ice Cover for Lake Erie near Toussaint River (1973-2000)

Percent Cover	0	5	10	20	30	40	50	60	70	80	90	95	100
Total Days	72	177	1	3	10	6	6	9	7	22	28	89	98
Percent of Total	13.6	33.5	0.2	0.6	1.9	1.1	1.1	1.7	1.3	4.2	5.3	16.9	18.6

As shown in Figures 37 and 39, very little ice formed in Lake Erie near the Toussaint River during the winter of 2001 – 2002. Ice with greater than 30 percent coverage was observed by NOAA at this location on January 2, 8, and 10, 2002 (Table B1), and by Environment Canada on January 7 and 21, 2001 (Table B2). NOAA observations include only one other occurrence of ice, on March 6, 2002 of 20 percent coverage, while Environment Canada reports that the area is ice free for all its remaining observations during the winter of 2001-2002. Compared with average ice cover for this region, the amount of ice formed for the 2001-2002 winter period was much less than normal. There was 80-100 percent ice cover for only 11 percent of the winter. This is 34 percent less than the average of 44.9 percent of the winter. Ice-free conditions existed for 19.9 percent of the winter (from NOAA data), which is 6.3 percent greater than the average of 13.6 percent shown in Table 16.

Lake Erie, near the Toussaint River, formed significant amounts of ice during the winter of 2002-2003 (Figures 38 and 40). Based on NOAA data, this region was 80-100 percent covered for nearly 11 weeks, which was a considerable amount of ice as compared to the previous winter. From 1 January 2003 to 15 January 2003, all of the ice was less than 30 cm thick, and a majority of that ice was less than 15 cm thick. The ice floe for that time period ranged between 20 m and 100 m wide. The region had shore fast ice from 15 January 2003 up to 12 February 2003, with all of the ice less than 70 cm thick and a majority of that ice less than 30 cm thick. This ice remained connected to land and did not move with the current or develop cracks. From 12 February 2003 to 26 March 2003, the ice thickness ranged from greater than 70 cm to 15 cm, with a majority ranging from 30 cm to 70 cm. Figure 41 and 42 are photographs of the ice formations taken 23 March 2003 in the vicinity of Area A8 in Figure 29. The size of ice floe ranged from 100 m to 2,000 m, with a majority ranging from 500 m to 2,000 m. For 1 week after 26 March 2003, there was less than 10 percent ice coverage, and then there was no ice present for the remainder of the season. Comparing this winter's ice cover with the average for this region, the amount of ice formed was greater than usual. There was 80-100 percent ice cover for more than 65 percent of the winter, which is almost 20 percent more than the usual 44.9 percent of the winter, and there was 0-30 percent ice cover for only 35 percent of the winter, which is nearly 15 percent below the average of 49.8 percent of the winter.

NOAA maintains a water-level gage near Marblehead, OH. This gage is approximately 20 miles east of the Toussaint River and is considered to be applicable to the SO placement sites (USACE 1993). The gage, number 906-3079, has been in operation since 1959, and its data can be obtained by going to

Figure 41. Ice formations photographed from Area A8 beach facing southeast taken 23 March 2003 (Courtesy of Mr. Ollie StClair and dog “Rush”)

Figure 42. Ice formations photographed from Area A8 beach facing northeast taken 23 March 2003 (Courtesy of Mr. Ollie StClair)

the Web site http://co-ops.nos.noaa.gov/ .Table B3 in Appendix B presents the monthly maximum and minimum instantaneous water levels along with the monthly mean water level at this station for September 20, 2001 to May 22, 2003. Figure 43 shows these data, along with the long-term mean, maximum, and minimum water levels. Figure 44 displays the daily mean water levels at this station, and Figures 45 and 46 display the hourly values during two ice-free periods when the SO were deployed, in which there were significant setdown and setup events.

The mean water level for the time the SO was first deployed (i.e., September 20, 2001) until just before it was recovered (i.e., May 22, 2003) was 0.9 ft lower than the long-term monthly mean (Figure 43). The minimum instantaneous water level dipped below the minimum mean monthly water level three times during the same period. These were during October 2001, February 2002, and February 2003. The maximum instantaneous water level stayed well below the maximum monthly mean for the entire period.

The Ohio State University (OSU) and NOAA GLERL maintain a Web site dedicated to predicting and posting pertinent Great Lakes data: the Great Lakes Forecasting System at http://superior.eng.ohio-state.edu/ . The Great Lakes Forecasting System posts charts that show the wave heights and direction forecasts for all the Great Lakes at noon that day. Due to the orientation of the coastline in the area of the Toussaint River, which is approximately southeast by northwest, and the presence of a northward extension of coast and an island chain just east of Camp Perry, relating these forecast waves to conditions at the beach where SO were placed, would require an analysis that exceeds the scope of the present study. The objective was to document the general wave conditions immediately offshore of the study area during the period in which the SO were deployed. To do this, the Great Lakes Forecasting System's forecasts for offshore of the Toussaint River area were used, but with the heights for waves coming from the south and southwest (which would be very small at the beach where the SO were deployed) set to zero. The resulting daily data for the deployment period are shown in Figure 47, and the wave-height and wave-direction distribution is given in Table 17.

A numerical hindcast study of Lake Erie wave conditions was conducted by Driver et al. (1991). The study presents 32-year (1956 to 1987) wave statistics for a station approximately 13.7 miles northeast of the area where SO were deployed. The 32-year mean significant wave height was 2.3 ft, and the largest wave was 8.5 ft from 88 deg. The mean wave height for the Great Lakes Forecasting System data for the deployment period, with waves from the south and southwest is 1.6 ft. However, it should be noted, that forecasts were not made from January 1 to mid-March in 2002, and to early April in 2003 (Figure 47), whereas the wave hindcasts used in the 32-year statistics included all months. During the deployment period, waves exceeding the hindcast-maximum height were forecast five times. The forecasts were 10 ft on October 17, 2001, and April 25, 2002, and 9 ft on October 25 and 27, 2001, and October 7, 2002.

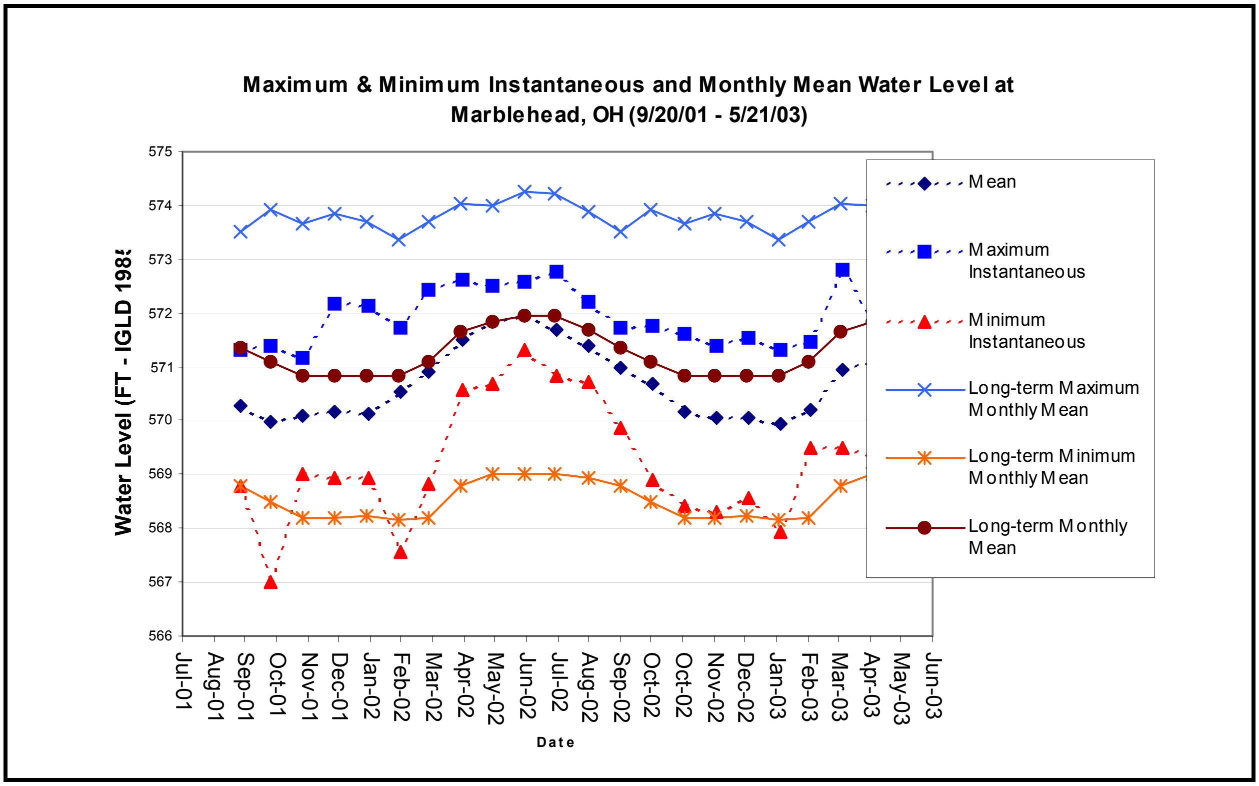


Figure 43. Monthly water levels applicable to Toussaint River area

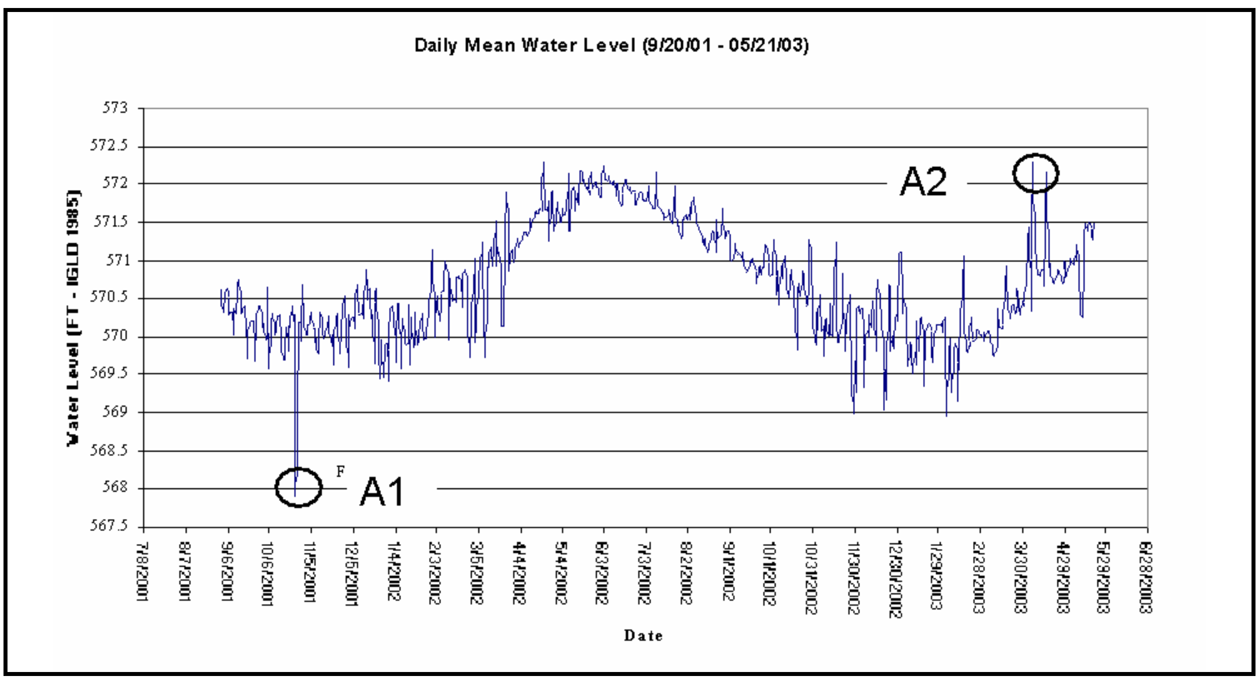


Figure 44. Daily mean water levels applicable to Toussaint River area

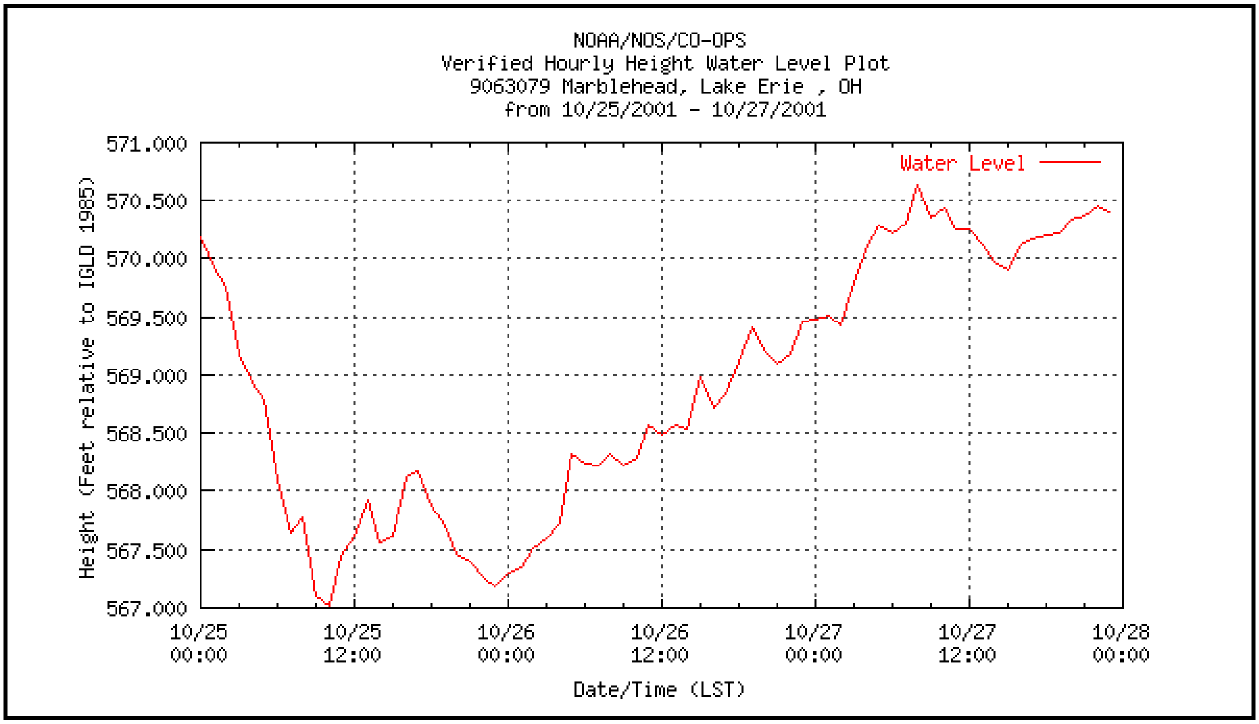


Figure 45. Hourly values during time of event circled and labeled “A1” in Figure 44

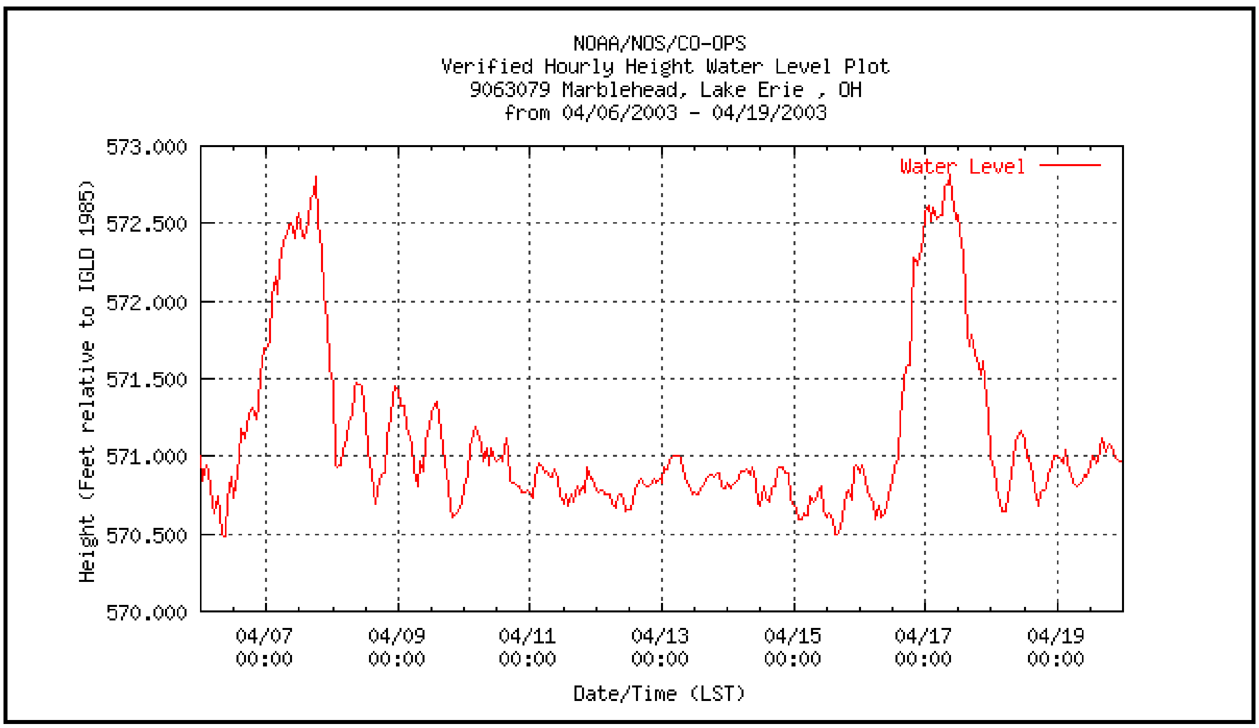


Figure 46. Hourly values during time of event circled and labeled “A2” in Figure 44

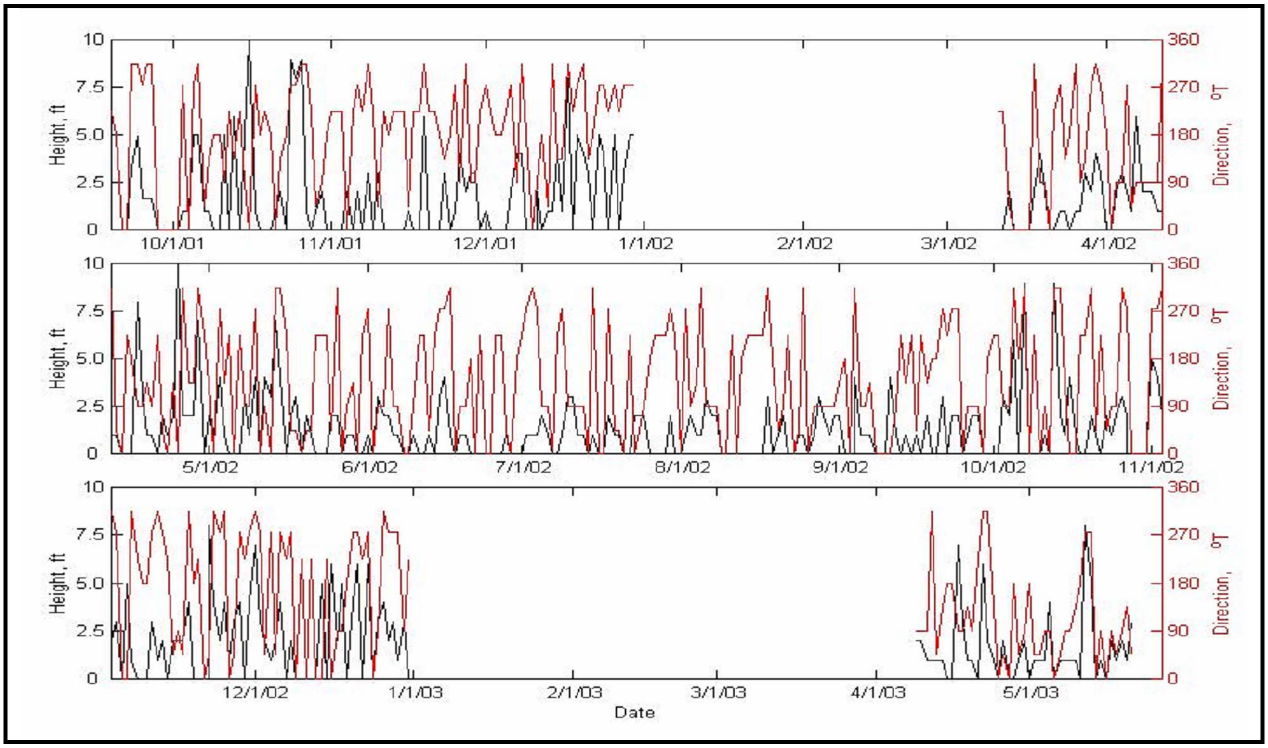


Figure 47. Daily forecast of wave heights near Toussaint River from Great Lakes Forecasting System

Table 17
Wave Height and Direction During Period SO Were Deployed

Wave Height (ft)	Wave Direction								
	N	NW	E	SE	S	SW	W	NW	Total
< 2	7	21	27	15	37	78	13	14	212
2 - 4	3	17	41	10	0	0	22	12	105
4 – 6	4	0	8	1	0	0	17	11	41
6 – 8	1	0	2	1	0	0	2	6	12
8 - 10	0	1	1	0	0	0	3	6	11
>10	0	0	0	0	0	0	0	0	0

NOAA maintains a wave-measuring buoy (buoy 45005) during ice-free months which is located approximately 29.9 miles east-northeast of the area where SO were deployed. The data for this buoy can be obtained from http://www.ndbc.noaa.gov/. Data from this buoy shows that 8.7 ft waves were observed on October 17 and 25, 2001, 4.4 ft-waves on April 25, 2002, 5.8-ft waves on October 27, 2001, and 5.5 ft waves on October 7, 2002. In comparison to the forecasts, waves exceeding the hindcast-maximum height were measured only once during the deployment period.

The wave conditions on October 25, 2001, which were forecast and observed at buoy 45005 to be approximately 9 ft, occurred at a time when the water level at Marblehead was measured to be 2.18 ft below Low Water Datum (LWD) (see

Figure 45) and 8.75 ft lower than the annual design water level for Marblehead. The waves were forecast to be from the west, and the low-water level is attributed to the strong winds that came from the west and caused a lake setdown. The buoy data show that large wave conditions extended into the next day, and that for a total of 30 hr, wave heights exceeded 6 ft. According to probability statistics from hindcast data in Driver et al. (1991), 9-ft waves would occur only once in 20-50 years. On April 17, 2003, 7-ft waves from the west were forecast. The NOAA buoy was not operational at this time. Though the water level was 3.08 ft above the LWD (see Figure 20) and 0.69 ft above the mean monthly mean, it was still 3.5 ft lower than the 10-year design water level. According to the hindcast study, the 7-ft wave height was higher than 94 percent of the wave heights during this time period, and is considered to occur once every 2 years.

Due to the difference in the number of months used in the hindcast study, as compared with the forecast data, little can be said about the mean wave height during the time the SO were deployed except that it was typical. Table 16 shows that a majority of the waves during the deployment had wave heights less than 2 ft. However, maximum waves were significantly greater than typical during the time SO were deployed.

6 Summary of Data Results

The purpose of this study was to investigate the possible movement of SO resulting from the action of waves, currents, and/or ice. To do so, distances computed by changes in the coordinates of individual SO must be evaluated in the context of the overall error associated with the survey system and methodology. The accuracy of the RTK GPS reading varied from SO to SO as a function of the distance from the base station, but the manufacturer's specifications for the system's precision for real-time and post-processed surveying are 1 cm + 1 part per million (ppm) root mean square (RMS) (approximately 0.03 ft) for horizontal measurements, and 2 cm + 1 ppm RMS (approximately 0.065 ft) for vertical fixes. The surveying device's accuracy and precision was much better than the accuracy and precision that was achieved with the field survey methodology. The uncertainties of the placement of the survey-rod tip on SO that could not be seen underwater from the surface, and the straightness and steadiness of the rod while the surveyor was trying to hold himself steady in the waves, need to be considered. The diver recovery helped with the issue of placement of the survey-rod tip, but introduced some different uncertainties in terms of the survey-rod orientation. The overall error budget can best be estimated by the surveyors. They estimate that distances computed from the changes in SO coordinates from deployment to recovery show migration of SO if they exceed 1 ft. These distances are shown in Figure 48, and summarized in the following paragraphs.

SO Deployed in Vicinity of Toussaint River

Eleven pieces of SO were deployed near the mouth of the Toussaint River. They are 60-1, 60-2, 90-2, 81M-1, 90-3, 106-1, 81H-1, 90-1, 81M-2, 60-3, and 90-5. Of these, 60-1 and 60-2 were deployed near the shoreline, and would have been visible to individuals walking on the beach. These two pieces of SO were never located after they were deployed, and most likely were picked up and removed by people.

Based on their observed locations relative to their deployed positions, two pieces of SO, 90-2 and 81M-1, apparently rolled down the sideslope of the river channel. SO 90-2, as surveyed during the December 2001 survey, had moved 7.39 ft, rotated 90 deg to become parallel to the river flow, and was found buried approximately 1 ft in sandy-clay. Communication with the acoustic tracking

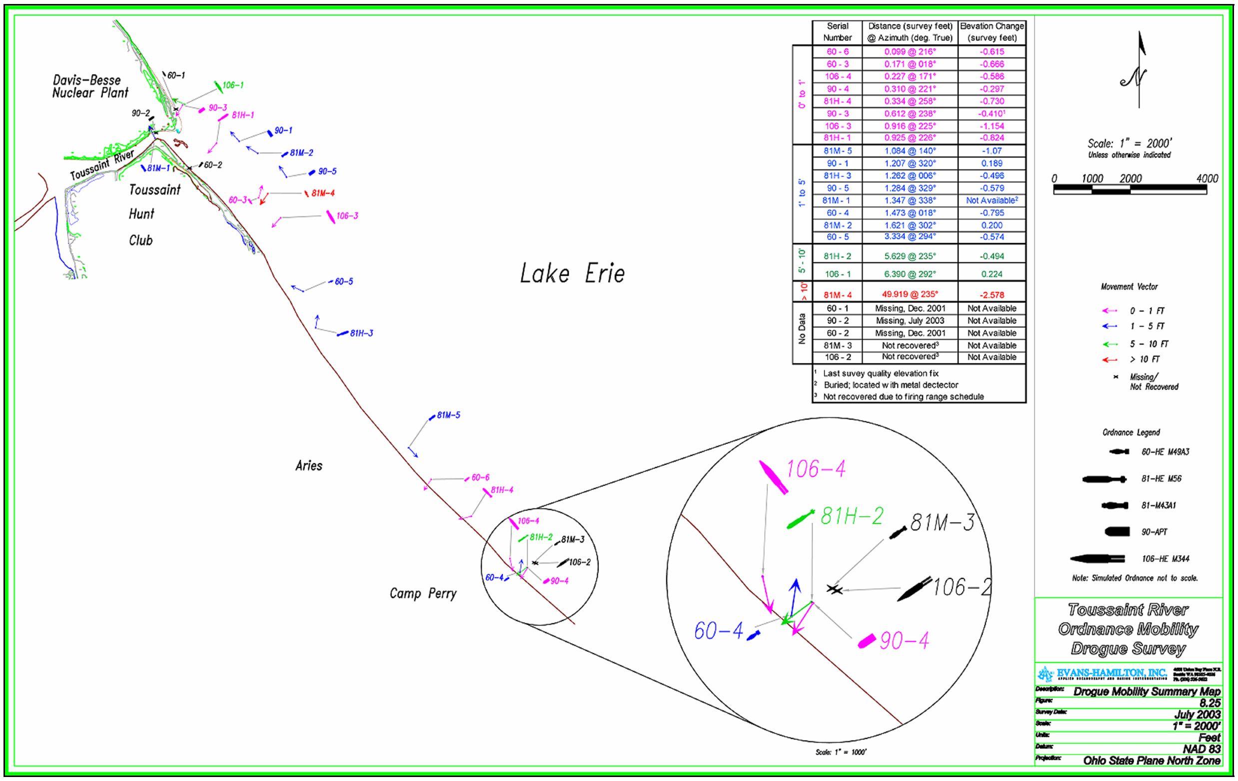


Figure 48. Distances computed by change in coordinates (from deployment to recovery) of SO during study

device in SO 90-2 was never reestablished after the December survey, and despite an extensive search, EOD divers were not able to locate and recover it at the end of the study. During the end-of-study recovery operations, it was found that a large tree had fallen on SO 90-2's last known position. This made it difficult to search in the riverbed underneath to locate the piece of SO, and with the apparent earlier failure of its acoustic tracking device, it was not possible to verify that it was still in the vicinity of its last known position. Acoustic communication with the other piece of SO placed in the river (81-M) was never established after its deployment. However, the divers did manage to locate it during recovery operations, and it was determined that the acoustic tracking device had malfunctioned. It also had rolled down toward the thalweg, moving 1.35 ft at 338 deg, and was found buried at a fuse-down attitude (i.e., the fuse end was buried 6 in. deep, while the tail fins were buried under 4 in. of the sandy-clay riverbed material).

As per the study's definition of SO mobility (i.e., changes in surveyed coordinates indicating movement of more than 1 ft, as previously discussed), four pieces of the remaining ordinance placed in the vicinity of the Toussaint River were mobile during the study. These are 106-1, 90-1, 81M-2, and 90-5. During the December 2001 survey it was found that 106-1 had moved 1.51 ft in a general shoreward direction (at 265 deg), and was found lying proud with the fuse still pointed toward the channel. In July 2003, during recovery operations, SO 106-1 was found to have moved 6.39 ft at 292 deg from deployment coordinates (FDC), and was half buried in sandy clay. SO 90-1 was found buried under 3 in. of compacted sand during the December 2001 survey in basically the same location as deployed. In September 2002 it was located approximately at the same location and still buried in sand. Due to the wave conditions, it was not precisely surveyed. In July 2003, 90-1 was found 1.21 ft at 320 deg FDC and buried under 8 in. of sand. SO 81M-2's computed change in location FDC in December 2001 was 0.74 ft at 330 deg (lying proud and oriented as deployed with fuse pointing lakeward at 60 deg) and then was found 0.56 ft at 035 deg FDC in September 2002, buried under 1 in of sand. During the September 2002 survey it was observed that 81M-2's fuse was oriented to 276 deg instead of 60 deg.(i.e., the SO's longitudinal axis had rotated from pointing lakeward, to pointing more toward the shore). In July 2003, the SO had moved 1.62 ft at 302 deg FDC with the fuse pointing downward at a 45 deg angle, and with the tail fins 8 in. below the sand. The SO's longitudinal axis had rotated back to pointing lakeward (i.e., 60 deg). Due to the deeper water depths during each survey after deployment, SO 90-5 was not resurveyed until July 2003. It was found buried under 4 in. of sand and had moved 1.28 ft at 329 deg FDC.

The three pieces of SO that by definition were not mobile during the study were 81-H, 90-3, and 60-3. SO 81-H1 was found approximately at its deployed location and orientation, and lying proud in December 2001, but was found to buried under 4 to 6 in. of sand during the May 2002 survey. The 15.467-ft movement for 81-H1, shown in Table 8 for the May survey, is a survey error. At recovery, it was found to be in a location 0.93 ft at 226 deg FDC, and buried under 3-in. sand on a flat bottom. While the deployment orientation for 81-H1 was with fuse pointing lakeward (approximately 60 deg), by the May 2002 survey, the fuse bearing was 140 deg, i.e., the SO's longitudinal axis was shore parallel. SO 90-3 was found at its deployed location and buried 0.5 ft below the lake bed during the December 2001 and September 2002 surveys. At recovery the computed change in positions was 0.619 ft toward shore (238 deg) and was almost completely uncovered (lying proud) on what was then observed to be compacted sandy clay. SO 60-3 was originally placed oriented shore-parallel (fuse pointing toward Camp Perry with a bearing of approximately 150 deg), and on top of what appeared to be the third major sandbar counting from the lake shoreward (i.e., the bar closest to shore). At deployment this location was above the water, but during every subsequent survey the SO was submerged. In December 2001 it basically had not changed coordinates FDC, but it's orientation had rotated 180 deg (i.e., instead of the fuse pointing to Camp Perry, it was pointing toward the navigation channel). It was partially buried. In September 2002, its change in coordinates FDC was 0.65 ft at 277 deg, and it was buried under 1 in. of sand. In July 2003, no measurable change in coordinates was observed, but the SO was buried under 0.5 ft of sand.

SO Deployed in Vicinity of Camp Perry

Five pieces of SO were deployed in the vicinity of Camp Perry. They were 81M-3, 106-2, 81H-2, 90-4, and 60-4. SO 81M-3 and 106-2 were only surveyed after deployment by augering through the ice during the February 2003 survey. This was due to a higher water level during the surveys than what existed during deployment. Due to the active firing range schedule at the time of the recovery operations in July 2003, neither piece of SO was recovered. During the February survey, SO 81M-3'S computed change in position FDC was 0.552 ft at 221 deg, and it was buried under several inches of sand. SO 106-2 was also found buried under several inches of sand in February 2003, and its surveyed position showed a 0.165 ft change at 221 deg FDC. Of the remaining four pieces of SO deployed near Camp Perry, one other, SO 90-4, was not mobile by definition. Its surveyed location FDC was 0.533 ft at 198 deg in December 2001, 0.479 ft at 208 deg in September 2002, and 0.31 ft at 221 deg when recovered in July 2003. It did, however, become progressively buried deeper in the sand during the deployment period. The burial depth went from 1 in., as observed in December, to 6 in. when located in September, to 16 in. when recovered.

Two of the five pieces of SO deployed in the vicinity of Camp Perry, 81H-2 and 60-4, were mobile by definition. SO 60-4 was initially placed at the water's edge (on sand and gravel), but it was observed to be almost completely buried during the December 2001 survey. The surveyed position at that time was, 0.21 ft at 018 deg FDC. This piece of SO was not found (although the radio ranging system was operational on the September 2002 survey, digging in the sand failed to locate the SO) until the July 2003 recovery operation, when its migration was calculated to be1.47 ft at 018 deg FDC. It was found buried under 8 in. of sand. SO 81H-2's location in December 2001 was 0.683 ft at 193 deg FDC. It was oriented as deployed (shore-parallel), and buried under 2 in. of sand. In September 2002, the computed FDC distance was 0.75 at 209 deg, and it was found buried under 14 in. of sand with the same orientation as when deployed. In July 2003, when it was recovered, the surveyed location showed a migration of 5.63 ft at 235 deg FDC, and it was found buried under 18 in. of sand.

SO Deployed in and Under Ice

Eight pieces of SO were deployed in, and under the ice, in February 2003. They were 106-3, 60-6, 81H-4, 106-4, 60-5, 81M-4, 81H-3, and 81M-5. They were all recovered in July 2003. Four of the eight pieces of SO, 106-3, 60-6, 81H-4, and 106-4, by definition did not migrate during the study. SO 106-3 was placed near the mouth of the Toussaint River where there was 12-in.-thick ice with 3 in. of water underneath (Figure 33). After surveying in the SO, the ice chips removed to make the deployment hole were put back into the hole. However, the water level did not return to the ice surface level. During the recovery operation in July, SO 106-3 was found buried under 16 in. of sand with approximately the same longitudinal axis orientation as when it was deployed. Survey results showed a movement of 0.92 ft at 225 deg FDC. SO 60-6 was placed near Camp Perry in 8 in. of ice that extended all the way to the bottom. During the recovery operation, it was found buried under 6 in. of sand with the same orientation as when it was deployed. Its surveyed coordinates showed a 0.1-ft movement at 225 deg FDC. The ice at the deployment location for SO 81H-4 also extended all the way to the lake bed. At this location, which was also near Camp Perry, the ice thickness was 23 in. SO 81H-4's survey results are

0.33 ft of movement at 258 deg FDC. SO 106-4 was the southeasternmost piece of the three SO ice deployments near Camp Perry. At its deployed location, the ice was 18 in. thick, and extended all the way to the bottom. At recovery, it was found buried in 6 in. of sand at 0.22 ft and 171 deg FDC.

Four pieces of ice-deployed SO migrated during the study. They were 60-5, 81H-3, 81M-4, and 81M-5. SO 60-5 was deployed after cutting a hole in 7-in-thick ice, and laying the SO on the sand/ice interface (Figure 30). After surveying in the SO, water and ice were poured back into the hole. This piece of SO appeared to be placed on the shore side of a sandbar, in-between the Toussaint River and Camp Perry, that protruded above the ice surface. When surveyed during the recovery operation, SO 60-5 had moved 3.33 ft at 294 deg FDC, and was found under 8 in. of sand with approximately the same longitudinal axis orientation as when deployed. SO 81H-3 was placed south of 60-6, closer to Camp Perry. The ice at this location was 23 in. thick and also extended all the way to the bottom. From the appearance of two sandbar crests above the ice surface, the SO was placed in the trough between them. One of these sandbars was also the one visible at SO 60-6's deployment location. When surveyed during the recovery operation, SO 81H-3 had moved 1.26 ft at 006 deg FDC, and was found half buried with its fuse end pointing toward 120 deg. Compared to the deployment orientation of 60 deg, the SO's longitudinal axis had rotated from an offshore perpendicular bearing to a more shore-parallel one. SO 81M-4 was placed near the mouth of the Toussaint River, on the shore side of the sandbar observed at 60-6's deployment location. The ice was 8 in. thick at this location, and extended all the way to the bottom (Figure 32). When recovered, it was found that SO 81M-4 had moved 49.99 ft at 235 deg FDC, and was buried under 6 in. of sand. Its fuse end was pointing toward approximately 300 deg; compared to the deployment orientation of 330 deg. SO 81M-5, was placed where the ice was frozen all the way down to the sediment (26 in. thick ice), at a location about midway between the Toussaint River and Camp Perry. When surveyed during the recovery operation, this SO had moved 1.1 ft at 140 deg FDC, and was found lying proud, with no change in orientation.

7 Discussion of Results

It is probably significant that during the first winter of the study (i.e., the winter of 2001-2002), there was very little ice formed in the vicinity of the study area, while during the winter of 2002-2003, there was extensive ice formation. In addition, the most notable wave events were on October 17 and 25, 2001 (measured deepwater wave heights of 8.7 ft), more than a year before the winter of 2002-2003. The reason these observations stand out in respect to the data results is, that before the summer of 2003 (i.e., up to and including the survey and deployment of SO in February 2003), with the exception of the one piece of SO (90-2) that apparently rolled down the river side slope before it was surveyed in December 2001, only one piece of SO had moved more than 1 ft. SO 106-1, deployed just to the northwest of the mouth of the Toussaint River, was found to have moved 1.51 ft at 265 deg FDC (i.e., toward the shore), when it was surveyed in December 2001. At that time it was lying proud, and was not surveyed again until the recovery operation in July 2003, when it was found to have moved 6.39 ft at 292 deg FDC. When recovered, it was half buried in sand. No other piece of SO, when surveyed, showed mobility of greater than 1 ft, until after the winter of 2002-2003, when the SO were surveyed and recovered. There were no surveys between February 2003, when ice covered the area, and the recovery of the SO in July 2003. Disregarding the additional piece of SO (81M-1) that, when located for the first time in July 2003, appears to have rolled 1.35 ft down the river side slope, the survey conducted in July, after the winter of 2002-2003, showed that a total of six pieces of SO, not deployed in the ice, had moved more than 1 ft. The results of this study do not support a hypothesis that large net movements of ordnance in the study area come from the action of waves and currents. Of the 16 pieces of SO deployed at the beginning of the study, only 106-1 showed movement greater than 1 ft that was probably due to the action of waves and currents. Over the study duration of approximately 21 months with the respective wave, water level, and ice effects encountered by the SOs during this period, study results indicate that ice was a major factor in SO mobility.

The action of waves and currents on the SO is probably most evident in the orientation changes that some of the SO underwent during the study, and in the fact that nearly all pieces of SO were buried during the study. The observed longitudinal axis rotations of the SO did not show a consistent pattern of shifting the SO to be parallel with incoming waves (as has been proposed by Kelly 2001). SO 60-3, which was deployed shore parallel, pointing toward Camp Perry, did rotate 180 deg between its deployment in September 2001 and the survey in September 2002, thereby remaining oriented shore-parallel. SO 81H-1 went from being perpendicular to shore, to being parallel to shore, during the study.

However, SO 81M-2, deployed near the mouth of the Toussaint River in September 2001, with an onshore-offshore longitudinal axis orientation (i.e., it was deployed pointing offshore at 60 deg), and found sitting proud in December with the same orientation as when it was deployed, was pointing toward the shore (276 deg) during the September 2002 survey.

Kelly (2001) observed that ordnance is buried by a scour-and-fill action of waves and currents to a depth equal to the diameter of the ordnance. However, SO 81H-2, which was deployed near Camp Perry was found buried under 14 in. of sand during the September 2002 survey. The 81H-2 ordnance has a 3-in.-diam. The GPS elevation reading showed no measurable change in elevation of the SO, indicating that for some SO, burial by bed form migration over the SO's location may have been a factor. The question of whether waves and currents in the study area can expose buried ordnance, thereby making the ordnance accessible to potential transport mechanisms, is significant. It is best addressed by considering only results prior to the winter of 2002-2003, to minimize the potential that ice was a factor. Of the 16 pieces of SO deployed in September 2001, only one was found buried and during a subsequent survey found exposed. SO 81H-1 was found sitting proud in December 2001, buried under 4-6 in. of sand in May 2002, and during the September 2002 survey, was found again sitting proud. However, SO 81H-1 was deployed directly offshore of the mouth of the Toussaint River, and it may have been under the action of the river's discharge.

Of the eight pieces of SO deployed in the ice, 50 percent of them were mobile by definition (i.e., changes in surveyed coordinates that showed movement of greater than 1 ft). SO 81M-4, which was deployed in 8 in. of ice on the shore side of a sandbar near the mouth of the Toussaint River, was found to have moved almost directly onshore for a distance of approximately 50 ft between its deployment in February 2003, and its recovery in July 2003 with an elevation change of -2.59 ft. While the methodology used for deploying the SO in the ice in February 2003 may not exactly be the same as the natural freezing process, the intent was to make it similar, and these results indicate that ice plays a major role in the mobility of ordnance in the study area. Figures 49 and 50, reportedly taken in study area A7 (Figure 42), show ice pileup (i.e., ice rafting). This rafting is caused by ice breaking up, moving offshore, then returning with an onshore wind and stacking up. The movement of sediment by ice is not well understood (Ashton et al. 1986), but Noble and Comfort (1982) describe the significant threat posed to submerged structures and pipelines by pressure ridges in moving ice sheets. These moving ice structures, when in contact with the bottom, may push proud SO along, and may also dig into the bottom and push buried SO along the lake bed. Ice freezing around exposed ordnance, plucking it from the bottom, and then transporting it when it moves, may be another mechanism contributing to ordnance transport. Figure 27 illustrates the ice's ability to freeze sediment at the ice/lake bed interface. Sediment taken up by the ice is visible in Figures 49 and 50. Figure 51 shows an undated picture of several ordnance items lying relatively exposed in the study area. If these items were covered by water and subsequently frozen in ice, it is conceivable that, given ice (horizontal) movement, that the ordnance could move with it.

Figure 49. “Zoomed in” photograph of Section A in Figure 42 (Courtesy of Mr. Ollie StClair)

Figure 50. “Zoomed in” photograph of Section B in Figure 42 (Courtesy of Mr. Ollie StClair)

SO 90-3, deployed near the Toussaint River, was found buried 0.5 ft below the lake bed in December 2001, and in September 2002. However, when it was recovered after the winter of 2002-2003, it was almost completely exposed. Possibly it had been exposed by the movement of ice over its location. SO 81H-2, deployed in the vicinity of Camp Perry in September 2001, showed no mobility greater than 1 ft through the September 2002 survey. It did, however, go from being buried in 2 in. of sand in December 2001, to being buried under 14 in. of sand in September 2002. As discussed earlier, the burial depth may have been the result of a bed form covering it up. However, when recovered in July 2003, it had moved 5.63 ft at 235 deg FDC, and it was found under 18 in. of sand. One possible explanation for this is that the ice pushed the lake bed, with the SO buried in it, toward the shore during the winter of 2002-2003. However, it may also have been first exposed by ice movement, then picked up by the ice and transported shoreward, where it was reburied by wave action. SO 60-4, initially placed at the water's edge near Camp Perry, was observed to be almost completely covered, and at its deployed location, in December 2001. It was not located again until the recovery operation in July 2003, after the winter of 2002-2003. At that time, it was found to have moved in an offshore direction 1.47 ft FDC, and was buried under 8 in. of sand. Again, it is possible that it was exposed by ice movement, and then transported offshore by wave/or ice action, and reburied by wave action.

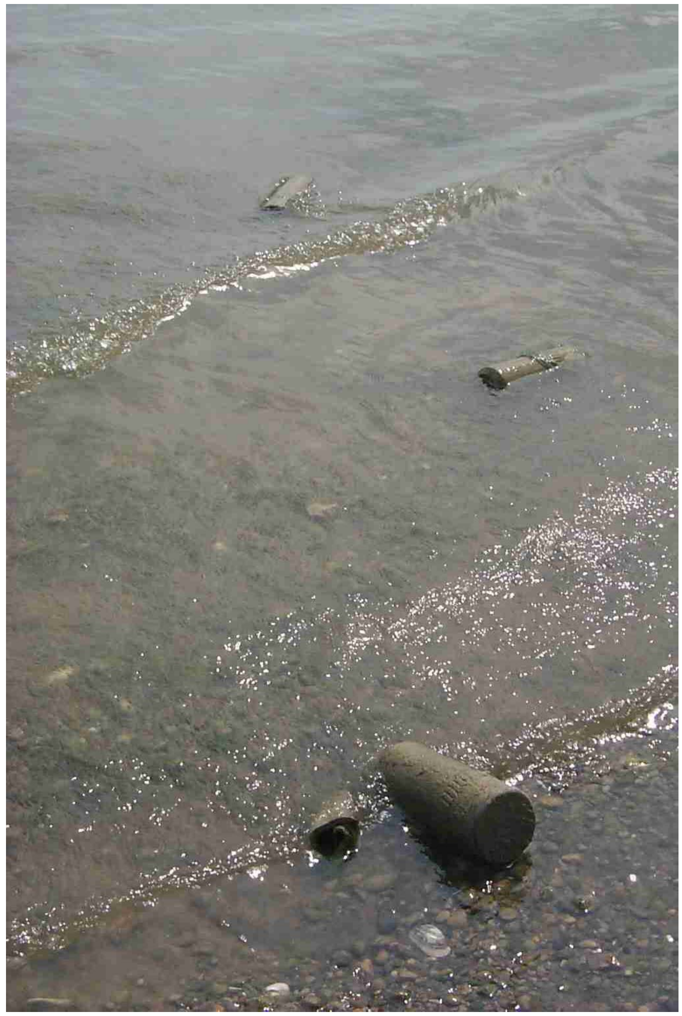


Figure 51. Exposed ordnance items in study area

8 Conclusions

The objective of this study was to determine if ordnance that might be located in areas adjacent to the navigation channel could be transported into the channel and subsequently be encountered by future dredging operations. Twenty-four pieces of SO were deployed in several nearshore areas in the vicinity of the Toussaint River in depths less than 6 ft. SO were deployed on both sides of the Toussaint River navigation channel where they could potentially be moved into the channel, and alongshore southeast of the Toussaint River in documented impact areas, where they could potentially be transported toward the river. These locations were chosen to provide information on movement as it relates to the potential of encountering ordnance during future dredging operations. Surveys to relocate and map the SO positions were conducted over an approximate 2-year period, during which the SO were exposed to a range of lake wave, current, water level, and ice conditions.

The ordnance concentration patterns documented in the study area by Pope et al. (1996), may be the result of a complicated interplay between the actions of waves, water levels, and ice. Onshore and alongshore SO transport vectors measured during the study are compatible with the conclusion of Pope et al. that "Ordnance in the nearshore bar field is subject to onshore migration and exhibits a tendency for limited along-shore transport."

Pope et. al. concluded that: "The mechanisms of ordnance transport appear to be a result of several factors (i.e., waves, ice, and human (dragging of fish nets toward shore). The contribution of each factor to the concentration patterns documented during this field study is unknown." Over the study duration, with its respective wave, current, water level, and ice effects on the SO, the results of this study indicate that the net transport of ordnance is largely due to ice. However, it is not known how it occurs, and to what extent waves, and water levels may play a role. Results of the study do not support a hypothesis that large net movements of ordnance in the study area can come from the action of waves and currents. These results are believed to be site-specific. The larger breaking waves, alongshore currents, and different breaker types found on most open-ocean coasts would probably mean that ordnance, if present, would have a greater potential for being moved by wave action. When the SO deployed in this study were on a sand bottom, the primary action of the waves and currents seems to have been to bury the SO under the lake bed. However, ordnance buried in the nearshore zone may be affected by breaking waves that could expose it (similar to a lag deposit). Changing lake water levels would expose varying lake bed locations to breaking waves. Overall erosion of the shore and changes in beach profile may also expose buried ordnance, thus making exposed ordnance available for transport, as seen in Figure 51. The results of this study indicate that ice can transport exposed ordnance onshore and offshore. However, these results also suggest that buried ordnance can be moved by ice, but whether ice, and or waves and currents, expose the ordnance first (allowing the ice to then move it) is unknown. In total, the study indicates that ordnance in Lake Erie is migrating in the vicinity of the Toussaint River navigation channel and has the potential to migrate into the navigation channel.

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Appendix A
Surveyed Locations of SO

Table A1
Surveyed Locations During Survey No. 1, December 2002

ID	Latitude (°N)	Longitude (°W)
60-1	Gone	Gone
90-3	41° 35' 20.83722"	83° 03' 37.59806"
106-1	41° 35' 21.04287"	83° 03' 36.85537"
90-2	41° 35' 13.59898"	83° 03' 46.72818"
81M-1	41° 35' 12.19338"	83° 03' 47.13298"
81H-1	41° 35' 11.02125"	83° 03' 25.80870"
90-1	41° 35' 11.59221"	83° 03' 18.04920"
60-2	Gone	Gone
81M-2	41° 35' 08.56675"	83° 03' 11.65336"
60-3	41° 34' 57.07114"	83° 03' 11.23964"
90-5	41° 35' 02.44274"	83° 03' 01.70107"
60-4	41° 33' 20.83576"	83° 01' 40.55455"
81M-3	41° 33' 23.33805"	83° 01' 35.40167"
81H-2	41° 33' 22.12495"	83° 01' 38.06260"
90-4	41° 33' 22.05108"	83° 01' 37.97143"
106-2	41° 33' 23.25761"	83° 01' 35.30142"

Table A2
Surveyed Locations During Survey No. 3, September 2002

ID	Latitude (°N)	Longitude (°W)
60-1	Gone	Gone
90-3	41° 35' 20.83676"	83° 03' 37.59180"
106-1	41° 35' 21.04287"	83° 03' 36.85537"
90-2		
81M-1		
81H-1	41° 35' 11.01714"	83° 03' 25.81252"
90-1	41° 35' 11.58431"	83° 03' 18.05907"
60-2	Gone	Gone
81M-2	41° 35' 08.56671"	83° 03' 11.63944"
60-3	41° 34' 57.07453"	83° 03' 11.24255"
90-5		
60-4		
81M-3		
81H-2	41° 33' 22.12656"	83° 01' 38.06178"
90-4	41° 33' 22.05338"	83° 01' 37.96864"
106-2		

Table A3
Surveyed Locations During Recovery, July 2003

ID	Latitude (°N)	Longitude (°W)
60-1	Gone	Gone
90-3	41° 35' 20.83432"	83° 03' 37.59892"
106-1	41° 35' 21.06933"	83° 03' 36.90884"
90-2	Gone	Gone
81M-1	41° 35' 12.20401"	83° 03' 47.13704"
81H-1	41° 35' 11.01593"	83° 03' 25.81173"
90-1	41° 35' 11.59969"	83° 03' 18.05351"
60-2	Gone	Gone
81M-2	41° 33' 22.10093"	83° 01' 38.11755"
60-3	41° 34' 57.07540"	83° 03' 11.23332"
90-5	41° 35' 02.45523"	83° 03' 01.70508"
60-4	41° 33' 20.84910"	83° 01' 40.54596"
81M-3	Not Recovered	Not Recovered
81H-2	41° 33' 22.10093"	83° 01' 38.11755"
90-4	41° 33' 22.05525"	83° 01' 37.96838"
106-2	Not Recovered	Not Recovered
60-5	41° 34' 33.04816"	83° 02' 55.75784"
81M-4	41° 34' 57.89419"	83° 03' 08.60789"
81H-3	41° 34' 23.61864"	83° 02' 51.31539"
106-3	41° 34' 51.95008"	83° 03' 03.58539"
60-6	41° 33' 44.77121"	83° 02' 11.39843"
81M-5	41° 33' 52.85137"	83° 02' 19.07910"
81H-4	41° 33' 35.30998"	83° 01' 57.40081"
106-4	41° 33' 24.41098"	83° 01' 44.04632"

Appendix B
Tables of Ice Cover and Water Level

Table B1
Ice Conditions on Lake Erie Near Toussaint River – 9/20/01 to 4/14/03 – NOAA

Date	Total Amount of Ice Coverage	Amount of Total			Thickness of Ice			Form of Ice – Size of Ice Floe		
		A	B	C	A	B	C	A	B	C
20-Dec-01	ICE FREE[(1)]	-	-	-	-	-	-	-	-	-
24-Dec-01	ICE FREE	-	-	-	-	-	-	-	-	-
2-Jan-02	9/10th +	5/10th	4/10th	-	5-15 cm	0 – 5 cm	-	0 – 10 cm	0 – 10 cm	-
8-Jan-02	9/10th	2/10th	7/10th	-	5-15 cm	0 – 5 cm	-	0 – 10 cm	0 – 10 cm	-
10-Jan-02	3/10th	3/10th	-	-	0 – 5 cm	-	-	0 – 10 cm	-	-
15-Jan-02	ICE FREE	-	-	-	-	-	-	-	-	-
21-Jan-02 to 27-Feb-02	ICE FREE	-	-	-	-	-	-	-	-	-
6-Mar-02	2/10th	0/10th	2/10th	-	5-15 cm	0 – 5 cm	-	0 – 10 cm	0 – 10 cm	-
11-Mar-02 to 16-Apr-02	ICE FREE	-	-	-	-	-	-	-	-	-
18-Dec-02	ICE FREE	-	-	-	-	-	-	-	-	-
25-Dec-02	ICE FREE	-	-	-	-	-	-	-	-	-
1-Jan-03	8/10th	4/10th	4/10th	-	0 – 5 cm	5-15 cm	-	0 – 10 cm	100 – 500 m	-
8-Jan-03	6/10th	0/10th	4/10th	2/10th	15 – 30 cm	5-15 cm	0 – 5 cm	20 – 100 m	20 – 100 m	0 – 10 cm
15-Jan-03	9/10th +	5/10th	4/10th	0/10th	15 – 30 cm	5-15 cm	0 – 5 cm	20 – 100 m	20 – 100 m	20 – 100 m
22-Jan-03	TOTALLY COVERED	2/10th	8/10th	-	30 – 70 cm	15 – 30 cm	-	Connected to Land[)]	Connected to Land[)]	-
29-Jan-03	TOTALLY COVERED	3/10th	7/10th	-	30 – 70 cm	15 – 30 cm	-	Connected to Land[)]	Connected to Land[)]	-
6-Feb-03	TOTALLY COVERED	5/10th	5/10th	-	30 – 70 cm	15 – 30 cm	-	Connected to Land[)]	Connected to Land[)]	-
12-Feb-03	8/10th	0/10th	2/10th	4/10th	30 – 70 cm	15 – 30 cm	T5-15 cm	20 – 100 m	20 – 100 m	20 – 100 m
19-Feb-03	9/10th +	1/10th	7/10th	1/10th	> 70 cm	30 – 70 cm	0 – 5 cm	100 – 500 m	500 – 2000 m	100 – 500 m
27-Feb-03	9/10th +	1/10th	7/10th	1/10th	> 70 cm	30 – 70 cm	15 – 30 cm	500 – 2000 m	500 – 2000 m	100 – 500 m
5-Mar-03	9/10th +	2/10th	6/10th	1/10th	> 70 cm	30 – 70 cm	15 – 30 cm	100 – 500 m	500 – 2000 m	100 – 500 m
12-Mar-03	9/10th +	2/10th	7/10th	-	> 70 cm	30 – 70 cm	-	20 – 100 m	100 – 500 m	-
19-Mar-03	9/10th +	2/10th	7/10th	-	> 70 cm	30 – 70 cm	-	20 – 100 m	100 – 500 m	-
26-Mar-03	9/10th +	2/10th	5/10th	2/10th	> 70 cm	30 – 70 cm	15 – 30 cm	20 – 100 m	500 – 2000 m	100 – 500 m
2-Apr-03	OPEN WATER	0/10th	-	-	> 70 cm	30 – 70 cm	-	-	-	-
9-Apr-03	ICE FREE	-	-	-	-	-	-	-	-	-
16-Apr-03	ICE FREE	-	-	-	-	-	-	-	-	-

Table B2
Ice Conditions on Lake Erie Near Toussaint River – 9/20/01 to 4/14/03 – Env. Canada

Date	Total Amount of Ice Coverage	Amount of Total			Thickness of Ice			Form of Ice – Size of Ice Floe		
		A	B	C	A	B	C	A	B	C
17-Dec-01	ICE FREE	-	-	-	-	-	-	-	-	-
24-Dec-01	ICE FREE	-	-	-	-	-	-	-	-	-
31-Dec-01	OPEN WATER	-	-	-	-	-	-	-	-	-
7-Jan-02	6/10th	6/10th	-	-	0- 5 cm	-	-	Unknown	-	-
14-Jan-02	OPEN WATER	-	-	-	-	-	-	-	-	-
21-Jan-02	9/10th	9/10th	-	-	0- 5 cm	-	-	Unknown	-	-
28-Jan-02 to 8-Apr-02	OPEN WATER	-	-	-	-	-	-	-	-	-
15-Apr-02	ICE FREE	-	-	-	-	-	-	-	-	-
2-Dec-02	ICE FREE	-	-	-	-	-	-	-	-	-
9-Dec-02	OPEN WATER	-	-	-	-	-	-	-	-	-
16-Dec-02	OPEN WATER	-	-	-	-	-	-	-	-	-
23-Dec-02	OPEN WATER	-	-	-	-	-	-	-	-	-
30-Dec-02	2/10th	2/10th	-	-	0- 5 cm	-	-	Unknown	-	-
6-Jan-03	9/10th +	1/10th	6/10th	3/10th	15 - 30 cm	5-15 cm	0- 5 cm	20 - 100 m	100 - 500 cm	Unknown
13-Jan-03	5/10th	1/10th	4/10th	-	5-15 cm	0- 5 cm	-	20 - 100 m	Unknown	-
20-Jan-03	TOTALLY COVERED	1/10th	7/10th	2/10th	30 - 70 cm	15 - 30 cm	5-15 cm	2 – 20 m	100 - 500 cm	Ice of Land Origin
27-Jan-03	TOTALLY COVERED	2/10th	6/10th	2/10th	30 - 70 cm	15 - 30 cm	5-15 cm	100 - 500 cm	100 - 500 cm	Ice of Land Origin
3-Feb-03	9/10th +	3/10th	6/10th	1/10th	30 - 70 cm	15 - 30 cm	5-15 cm	100 - 500 cm	100 - 500 cm	100 - 500 cm
10-Feb-03	TOTALLY COVERED	5/10th	5/10th	-	30 - 70 cm	15 - 30 cm	-	100 - 500 cm	100 - 500 cm	-
17-Feb-03	9/10th +	1/10th	7/10th	2/10th	> 70 cm	30 - 70 cm	15 - 30 cm	100 - 500 cm	500 - 2000 m	100 - 500 cm
24-Feb-03	9/10th +	1/10th	7/10th	2/10th	> 70 cm	30 - 70 cm	15 - 30 cm	100 - 500 cm	500 - 2000 m	100 - 500 cm
3-Mar-03	9/10th +	2/10th	7/10th	1/10th	> 70 cm	30 - 70 cm	15 - 30 cm	100 - 500 cm	500 - 2000 m	100 - 500 cm
10-Mar-03	TOTALLY COVERED	2/10th	8/10th	-	> 70 cm	30 - 70 cm	-	20 - 100 m	Ice of Land Origin	-
17-Mar-03	TOTALLY COVERED	2/10th	8/10th	-	> 70 cm	30 - 70 cm	-	20 - 100 m	Ice of Land Origin	-
24-Mar-03	OPEN WATER	-	-	-	-	-	-	-	-	-
31-Mar-03	OPEN WATER	-	-	-	-	-	-	-	-	-
7-Apr-03	OPEN WATER	-	-	-	-	-	-	-	-	-
14-Apr-03	ICE FREE	-	-	-	-	-	-	-	-	-

Table B3
Maximum and Minimum Instantaneous and Monthly Mean Water Levels (ft) at Marblehead, OH - NOAA

2001	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**570.28**	**569.98**	**570.08**	**570.15**
Maxi-mum	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**571.32**	**571.4**	**571.17**	**572.16**
Mini-mum	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**568.8**	**567.02**	**569.03**	**568.93**
2002	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	570.14	570.55	570.9	571.51	571.83	571.94	571.68	571.41	571	570.7	570.15	570.06
Maxi-mum	572.12	571.73	572.43	572.61	572.49	572.57	572.76	572.21	571.71	571.78	571.63	571.38
Mini-mum	568.94	567.55	568.83	570.58	570.67	571.32	570.83	570.74	569.88	568.89	568.41	568.29
2003	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	570.07	569.95	570.2	570.95	571.08	-	-	-	-	-	-	-
Maxi-mum	571.53	571.31	571.48	572.82	571.77	-	-	-	-	-	-	-
Mini-mum	568.55	567.95	569.48	569.5	569.35	-	-	-	-	-	-	-

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In support of the U.S. Army Engineer District, Buffalo, the U.S. Army Engineer Research and Development Center conducted a 2-year study of the movement of simulated ordnance (SO) deployed in Lake Erie near the mouth of the Toussaint River. The Toussaint River is adjacent to the former Erie Army Depot, a formerly used defense site (FUDS) that contains approximately 3 miles of lake front. The objective of this study was to determine if ordnance that might be located in areas adjacent to the navigation channel could be transported into the channel and subsequently be encountered by future dredging operations.

15. SUBJECT TERMS

Ordnance	Migration	Waves
Unexploded Ordnance (UXO)	Transport	Ice

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