From 1946 until 1970, approximately 4,000 containers of low-level radioactive waste material were disposed of at the "Foul Ground" disposal site located 40 km east of Boston, Massachusetts. In 1980, public and Congressional concern was expressed over the potential public health hazard from these discarded wastes.

In September 1981, the Environmental Protection Agency contacted the National Ocean Survey and requested a side-scan sonar survey to be conducted at disposal sites in Massachusetts Bay. The purpose was to identify those areas of the bottom which might contain radioactive waste disposal containers. This survey showed areas of the disposal sites littered with a considerable amount of material. Results of the survey can be applied to designing photographic and benthic sampling activities at the sites.

The purpose of this paper is to present the technical findings of a side-scan sonar (SSS) survey of the Massachusetts Bay disposal site, and lay the groundwork for subsequent monitoring activities.

The concern over the disposal of radioactive material in the ocean stems primarily from the effects of these wastes upon public health. Only a limited amount of research has been conducted at the Massachusetts Bay site upon these effects. However, the site deserves special attention since it is in the shallowest water (less than 100m), nearest the coast (15 to 20 km), and in the vicinity of an active coastal fishery. In addition, a perceived concern existed that there may be an impact upon man. There is a high interest in locating and observing the radioactive materials containers and assessing the degree - if any - to which these radioactive materials have leaked and migrated from the dumpsite.

Available information supports the position that there has been no significant harm to man or to the environment as a result of past dumping. However, this conclusion is based primarily upon present knowledge of radioactivity from scientific hypotheses, and from testing on land and in laboratories, but not from results of actual marine monitoring.

The waste material generally came from commercial and medical sources and from defense installations located near the U.S. coastline. It included broken glassware, ashes, animal carcasses, and assorted laboratory apparatus used in medical experiments. As a rule, the wastes were placed in a container (a steel drum) and subsequently "encased" in concrete. This procedure served three purposes. First, it ensured that the containers sank rapidly to the bottom; second, it provided protection to personnel handling the material; and third, it furnished a barrier to the release of the material until the radioactivity decayed to background levels.

Vessels used during the disposal operation were usually a coastal tug and a barge. Only very general instructions were provided by the U.S. Army Corps of Engineers to the vessel operator describing the location of the disposal site - the vessels were to proceed on an approximate heading for a fixed distance from Boston Light. The vessels were not equipped with precision navigation equipment and were often out of sight of land. Navigation was by magnetic heading and estimated speed. This resulted in a potentially large disposal area.
However, a Coast Guard buoy was maintained at the primary disposal site during a portion of the disposal operation.

In order to conduct a monitoring survey, it was first necessary to know the location of the potential sources of radioactivity. The Environmental Protection Agency (EPA) contacted the National Ocean Survey (NOS) to request assistance in locating those areas of Massachusetts Bay which might contain the radioactive waste disposal containers. The problem confronting NOS was to design and implement a survey which would provide an assessment of the areas where the disposal containers could most likely be found, given a large degree of uncertainty in terms of location and container size.

SURVEY APPROACH

The objective was to locate "concentrations" of contacts at the sites in Massachusetts Bay. This was accomplished by a side-scan sonar (SSS) survey of three areas recognized as those where containers were most likely located. The survey was expected to provide data which could be utilized to define the overall extent and nature of future monitoring at each disposal site.

The SSS is a technique used to distinguish features on the sea floor as well as obstructions in the water column. An acoustical beam of a fixed frequency is emitted by a "fish" which is towed through the water at an appropriate depth and speed. The beam is very narrow in the horizontal plane, yet sufficiently broad in the vertical to obtain echoes from a position on the bottom directly below the transducer to points 500 m or more abeam. This combination of the beam shape and the very short length of the acoustical pulse gives side-scan sonar the capability to resolve small topographic irregularities and small objects on the sea floor. The returning signal is recorded upon a paper strip chart in a form which appears as a flat plane topographic map. From this chart, a skilled observer can determine the general condition of the sea floor topography as well as make an analysis of objects upon the sea floor.

SURVEY SITES

The primary site selected for the survey was the "Boston Foul Ground" (See figure 1.). This site has been used for the disposal of material for many years, including dredge material, rubble, wrecks, and munitions in addition to the low-level radioactive waste material. Hydrography at the site was conducted by the Coast and Geodetic Survey in 1967 and later detailed bathymetry was part of the Disposal Area Monitoring System project in cooperation with the U.S. Army Corps of Engineers. The major bathymetric features at the Boston Foul Ground disposal site are the Stellwagen Bank in the northeast corner and a circular mound in the north central portion of the site. The remainder of the site is extremely flat, although a small depression exists near the center. This depression contains fine black spoil material, possibly from the Charles River Dam Project. The depth of water at the disposal site ranges from 55 to 100 m. Two additional sites were identified as possibly containing disposal material. These are designated as Areas 2 and 3 on figure 1.

SURVEY OPERATIONS

The NOAA Ships RUDE and HECK, assisted by personnel from NOS's Atlantic Marine Center and Office of Oceanography and from the EPA's Office of Radiation Programs, conducted the survey. The survey was conducted from September 21 to October 9, 1981. Area 1 was thoroughly searched (100 percent or greater coverage) and reconnaissance lines were run in Areas 2 and 3. Representatives of the manufacturer were present during most of the survey. Also, an EPA representative participated in order to facilitate the transfer of information for use in the subsequent EPA monitoring survey.

A Klein model 531 SSS System equipped with both a 100 kHz and a 500 kHz towfish and a 200 m lightweight towcable was used during all operations. All equipment was tested and calibrated by Klein Associates, Incorporated. The 100 kHz towfish was used for a majority of the operations. The 500 kHz towfish was used for test purposes and as a check of the 100 kHz towfish. A Raytheon R2640W navigational echo sounder was operated during the survey.

Primary positioning control for this project was the Hastings Raydist DRS-H System operated in a range-range mode. Backup control was
the Del Norte Trisponder System. Both systems
were in use during the project, and positioning
data for both systems were simultaneously
recorded. The accuracy of the ship's position
was ± 10 meters.

DETERMINATION OF CONTACT POSITIONS

Determining the position of the towfish was
a major concern. The towfish was some distance
behind the ship and possibly displaced to one
side because of the current. The effect of the
current was not determined in this project;
i.e., the towfish is assumed to be directly be-
hind the ship. To determine the distance behind
the ship, the following technique was used:

1. The amount of towcable deployed was
recorded.

2. The average depth of the towfish was
determined by estimating its average altitude
over the bottom based on an examination of the
SSS records. The towfish depth then could be
determined by knowing the water depth which
had been recorded by the fathometer.

3. The Pythagorean theorem was used to
determine the maximum distance which the towfish
trailed behind the ship. To this distance was
added the distance from the ship's Raydist
antenna to the point at which the towcable was
measured—20 m. The actual distance was some-
what less than this total, since the towcable was
not in a straight line, but was in a
catenary. The correction for the catenary was
found to be approximately 12 m in Area 1. The
position of the towfish was not calculated for
each ship's position, but an average offset
correction was calculated based on the average
depth of water. The offset was determined to be
from 75 to 100 m.

SEARCH STRATEGY AND DATA ANALYSIS

The three areas investigated during the
project are indicated on figure 1, and are
defined as follows:

Area 1 - A 1-nautical mile radius circle
centered at latitude 42°25.7'N., Longitude
70°36.0'W. This area was investigated with a
100 kHz towfish set on the 100-m range with 90-
and 136-m line spacing. This achieved area
coverage of from 160 to 200 percent.

Area 2 - A 1-nautical mile radius circle
centered at latitude 42°23.3'N., Longitude
70°40.6'W. This area was investigated with a
100 kHz towfish set on the 100-meter range with
453-m line spacing. This achieved area
coverage of approximately 43 percent. Portions of
the area also were investigated with a 500 kHz tow-
fish on the 50- or 75-m range as a comparison to
the 100 kHz towfish.

Area 3 - A 1-nautical mile radius circle
centered at latitude 42°26.9'N., Longitude
70°40.0'W. This area was investigated with a
100 kHz towfish set on the 100-m range with
498-m line spacing. This achieved area coverage
of approximately 38 percent.

Since the purpose of this project was to
find concentrations of bottom debris, it was
necessary to develop a procedure whereby areas
of the bottom which appeared to contain waste
disposal containers could be identified,
indexed, and subsequently analyzed for use in
the design of a follow-on survey. Given the
uncertainty of the disposal operation, it was
not possible to determine if the SSS contacts
were radioactive waste containers. However, the
records contained a great deal of information
for use in the design of subsequent monitoring
endeavors.

The following analysis was performed upon
the SSS records:

1. The SSS sonographs were visually
examined. Areas showing concentrations of bot-
tom debris were delineated and identified by a
letter code. Figures 2, 3, and 4 are typical
sonographs from Survey Area 1.

2. The delineated areas were then plotted
on a sonar contact overlay in their actual geo-
ographical positions and were indexed to the
sonographs by a letter code.

3. A preliminary analysis of the areas
plotted on the composite sonar overlay plot was
conducted in order to provide additional informa-
tion as to the character of the ocean bottom and
the concentrations of debris in the search
areas.

The analysis of the SSS information for
Area 1 is shown in figure 5. Those areas which
contained a medium to high density of targets
are indicated by dark shading. A narrative
description is contained in the following
section.

DESCRIPTION OF FINDINGS

Area 1 encompasses the Boston Foul Grounds
for industrial wastes and a majority of the foul
grounds for dredge spoils. Extensive evidence
of the dumping of both industrial wastes and
dredge spoils can be seen in the northern and
western portions of the circle. Scientific
Applications Incorporated, which has investi-
gated the foul grounds under contract to the
U.S. Army Corps of Engineers, indicated that
debris of all kinds are present. It is
extremely difficult, if not impossible, to
differentiate between containers of low-level
radioactive wastes and the remaining debris.

Area 1 can be divided into four subareas
based on bottom characteristics. The out-
standing characteristic of the northern subarea
(shown on figure 5 as being bounded on the south
by a dashed line) is a relatively uniform bottom
FIGURE 2

FIGURE 3

FIGURE 4

TYPICAL SIDE-SCAN SONOGRAPHS FROM SURVEY AREA 1
interspersed with a large number of randomly spaced individual contacts. These contacts may be containers which were individually dumped from a vessel or they may be rocks left by glacier activity. The southeast subarea (the area bounded on the north by the XXX line) consists of an extremely uniform bottom interrupted only by what appears to be a few dredge spoil dumps. The third subarea, the extreme northeastern portion of the circle, is an extension of the Stellwagen Bank and shoals rapidly from 90 to 54 m. This area appears to contain little unnatural material. Depth contours have been drawn in this area to portray bathymetry. Ther remaining subarea contains the majority of the bottom contacts. These contacts likely include natural bottom material, dredge material, dredge spoil, industrial wastes, and possible containers of low-level radioactive waste. The greatest concentration of bottom contacts is a band running in a NNW to SSE direction about 0.25 to 0.50 nautical miles to the west of the center of the area. Also, in this area is a 74-m shoal centered at Latitude 42°26.2'N, Longitude 70°35.0'W.

Area 2 has relatively uniform bottom characteristics. There are no obvious signs of the dredge spoil that appear in Area 1. There are fewer signs of debris of any type than are seen in Area 1. The bottom material which were found are less concentrated than in Area 1.
Area 3 has less uniform bottom characteristics than Area 2. Relatively large areas of high-density contacts occur within this area. It appears that some of these large areas may contain natural deposits. Again, there are no obvious signs of dredge spoil dumping.

SUMMARY AND CONCLUSIONS

The results of the survey indicated that the bottom Massachusetts Bay, within a 1-nautical mile radius of the primary disposal site center (Area 1) is littered with a considerable amount of material, some of which may be the waste containers. The overall distribution of the objects display no particular pattern. A considerable area of the disposal site failed to show any targets indicating either no dumping had taken place, or the material has been buried by sediment.

The use of SSS did not enable us to pinpoint the locations of containers of low-level radioactive waste, since it was not possible to differentiate between these containers and other debris in the area. However, the SSS did allow us to identify areas of debris concentrations in which the likelihood of locating radioactive waste containers should be improved. These areas should be investigated with a direct visual observing technique such as television, still photography, or a submersible. Following this, a sampling survey can be developed for monitoring sediments and bottom dwelling organisms with a higher probability of being near the disposal containers.

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DISCLAIMER

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REFERENCES

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