SCIENCE APPLICATIONS, INC.

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PRECISION DISPOSAL OPERATIONS USING A COMPUTERIZED LORAN-C SYSTEM

DAMOS CONTRIBUTION #12

30 MAY 1980

Submitted to:

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INTRODUCTION

During 1979 and 1980, the New England Division of the US Army Corps of Engineers has been conducting a carefully managed and monitored program of dredge material disposal at the Central Long Island Sound Disposal Site. This program has been concerned with the coverage or "capping" of enriched material from Stamford Harbor with cleaner material from New Haven. This capping procedure resulted in a steep-sided compact mound of spoil material (Figure 1) that was developed by point dumping of material at a taut-wire moored buoy. Consequently, when additional capping material was available for disposal, it was necessary to dump this material at some distance from the buoy to avoid excessive shoaling of the mound.

Two general areas for disposal were identified: one, approximately 300 meters west of the buoy where some Stamford material was exposed, and second, around the southern margin of the spoil mound where additional material would increase the thickness of capping. Since placement of a series of taut-wire buoys to control this disposal would be cost prohibitive, an alternate plan using computer enhanced Loran-C control was initiated to manage the disposal operation.

An additional benefit derived from the enhanced Loran-C approach to disposal is the ability to monitor and manage the dumping procedure. During this operation, Loran-C data were recorded at five (5) minute intervals during transit to the site and more frequently as specified during the dumping operation by the inspector.

INSTRUMENTATION

The Navigation system installed aboard the tug ERNEST M was a prototype of a sophisticated microprocessor controlled navigation system under development by Science Applications, Inc. This prototype system (Figure 2) consisted of an APPLE II microcomputer equipped with a real time clock, a magnetic disk recording system and a video monitor. The Computer was interfaced with a Northstar 6000 Loran-C receiver equipped with a navigation pack which provided serial data output through a Northstar 6700 interface unit. During operation this

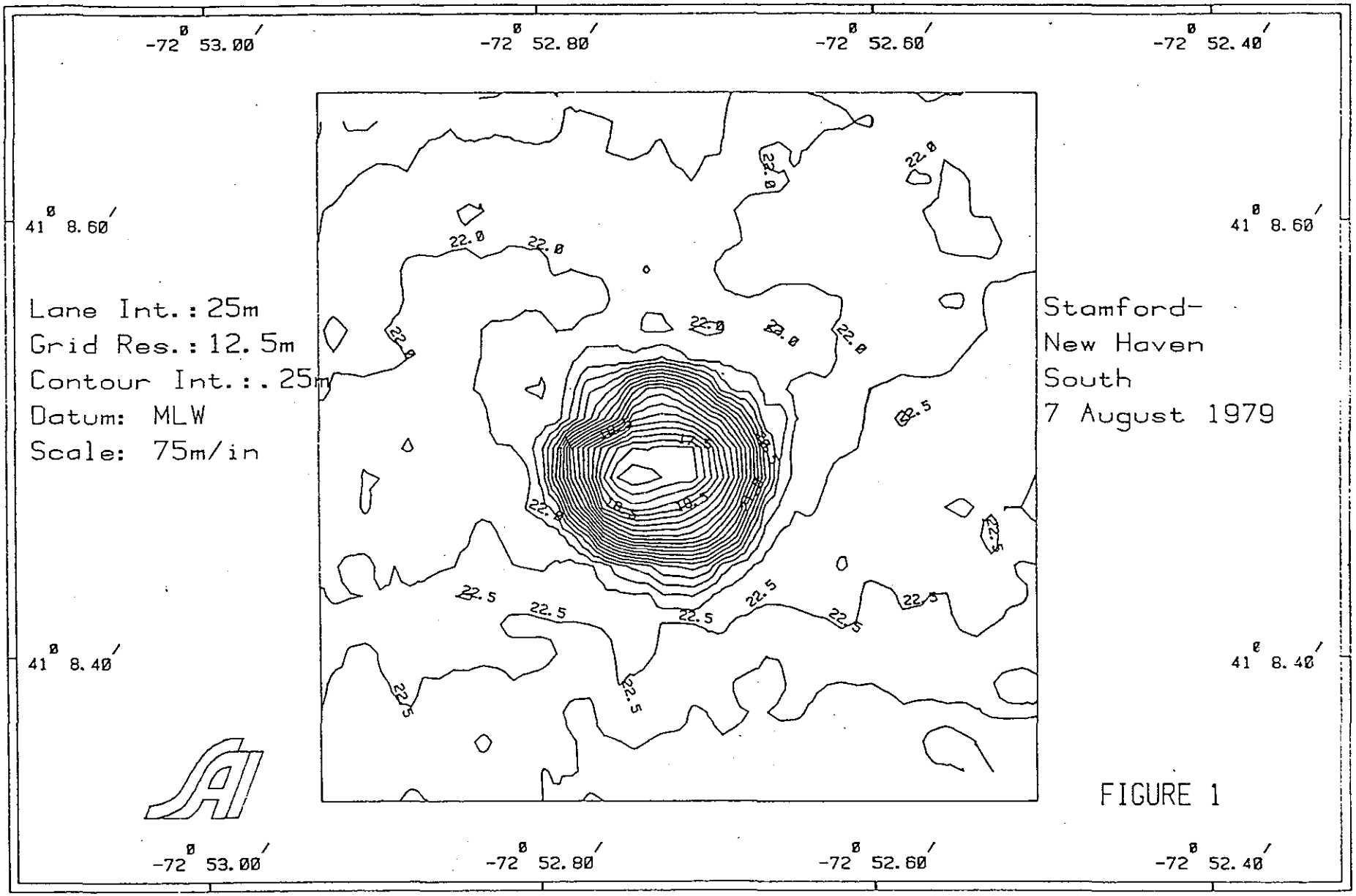

-72° 53.00′
-72° 52.80′
-72° 52.60′
-72° 52.40′
41° 8.60′
41° 8.40′
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 August 1979
22.0
22.5
18.5
17.5

FIGURE 1

SAI APPLE II NAVIGATIONAL SYSTEM

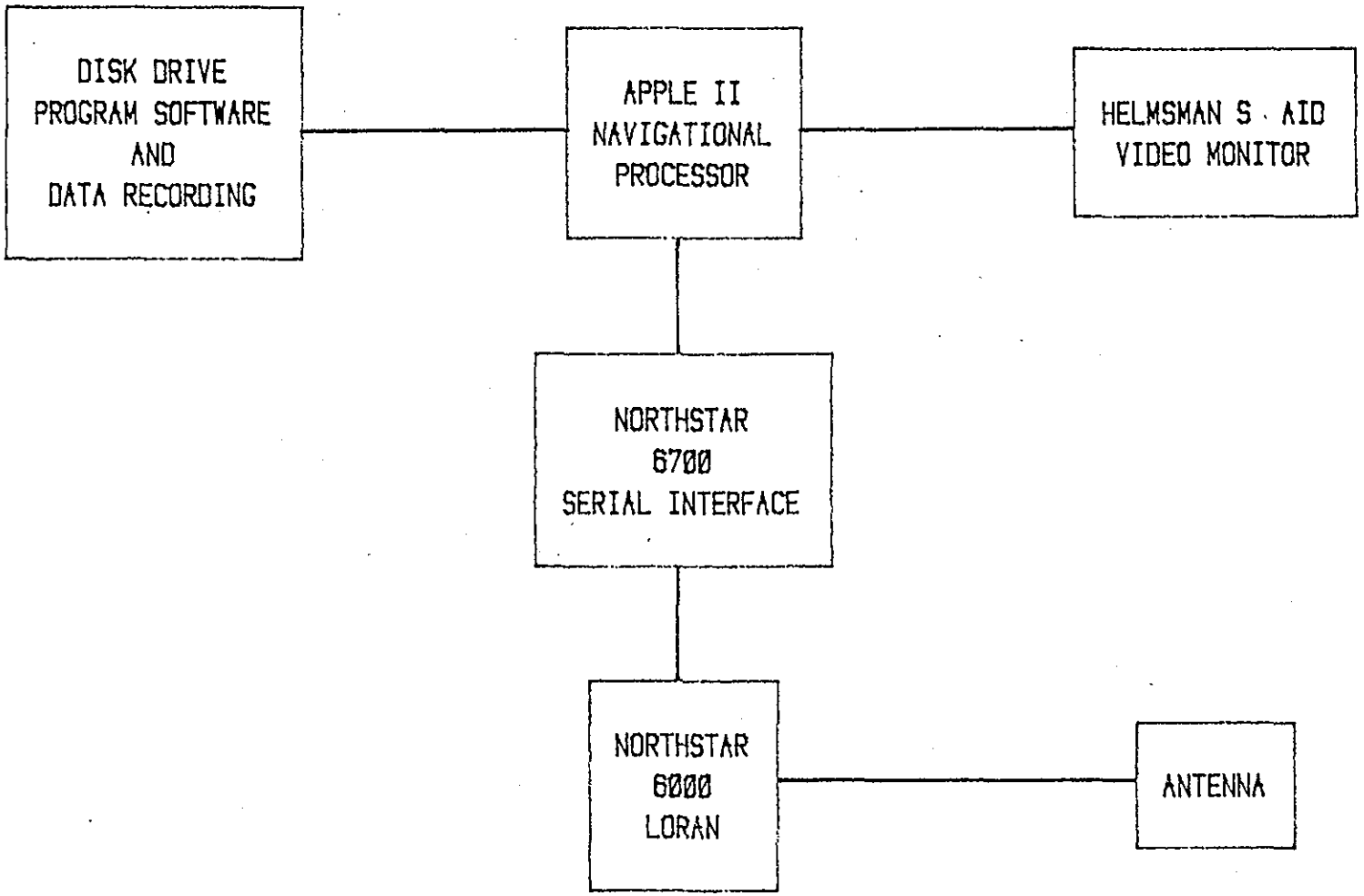


FIGURE 2

Loran-C receiver provided the computer with data at a variable rate between 2 and 7 seconds. Newer versions of the interface are available, however, which can generate data at a constant two second repetition rate.

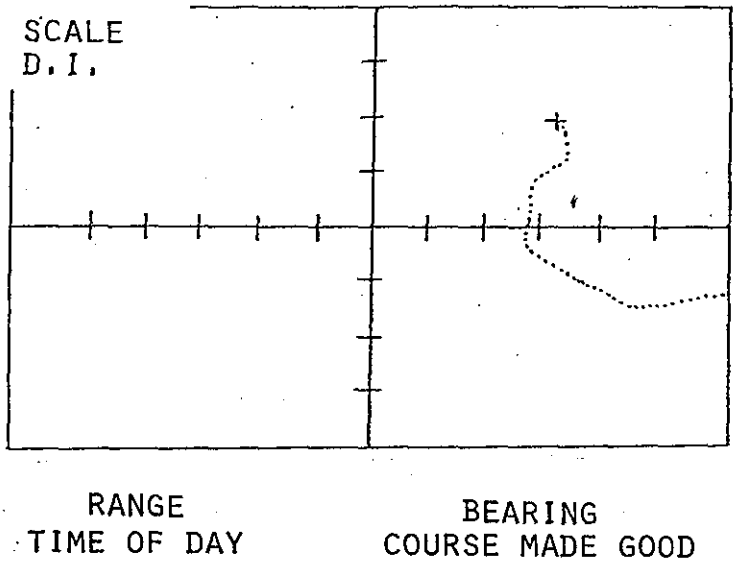
The Loran-C time delays after processing by the computer, were used to determine a series of navigation parameters including:

- Latitude and Longitude coordinates
- Range and bearing to destination
- Course and speed made good

These parameters were then used to provide navigation information to the helmsman through the video display. In order to maintain simplicity on this prototype unit only one display was available as shown in Figure 3. The center of the large cross represented the destination or disposal point. The scale of distance between tick marks on the large cross varied automatically depending on distance to the point and was displayed in the upper left corner of the screen. A minimum of 10 meters/division was used as the tug and scow approached the disposal point. On all displays the ship was designated with a small cross (+) and the ships track was maintained as a series of sequential crosses indicating previous position.

Time of day, range and bearing to the disposal point and course made good were displayed at the bottom of the video screen and updated with each new data set. The inherent variability of raw Loran-C data, requires the application of smoothing functions before the calculated parameters are displayed for use by the helmsman. These smoothing functions must be applied in a manner that does not degrade the overall calibrated accuracy of the Loran data.

In addition to the visual display of data, time of day and position information are recorded on mini-floppy disks to provide a capability for monitoring the disposal operation. Once the system is started these data are recorded at 5 minute intervals; however, a special function key on the computer permits the disposal inspector to override the sequence and record the positions at the start and end times of (or any time during) disposal. This key also sets an indicator bit designating the fix as a disposal location.



VIDEO DISPLAY

RANGE AND SCALE ARE IN METERS
BEARING IS MAGNETIC

FIGURE 3

The software generated for this prototype system contains other features specifically oriented toward control of dredge material disposal, including:

- special function keys to designate a number of disposal points, each defined prior to the operation and specified by a particular code.
- special function key to reverse the start and end points thus providing navigation control back to the dredging site after disposal
- special function key to record calibration data at the start of each disposal trip
- special function key to set and maintain a specific scale on the video display.

In summary, the system used at the Central Long Island Sound Site was a prototype unit developed to manage the disposal operation for a short period of time. Although the system proved adequate for this purpose, future units could be more compact, better packaged and more flexible in terms of video displays and data presentation.

PROCEDURES

The value of a navigation system such as the unit described here depends to a large extent on the ability of ship personnel to utilize the data available. Consequently, the system must be easy to operate, must not interfere with normal ship procedures, must present the data in a clear and understandable manner and must provide an efficient method for conducting the disposal operation without undue delay. The system described earlier was able to accomplish all of these requirements based on the following procedures.

Prior to installation of the system, calibration of Loran-C in the operating area was conducted by measuring the time-delay readings at the disposal buoy and at a channel buoy (No. 7) at the entrance to New Haven Harbor. Using these data the locations of specific disposal points were calculated in terms of Loran-C time delays relative to the disposal buoy.

Another approach to calibration, where disposal buoys are not available would utilize precision micro-wave navigation systems

to provide absolute position versus Loran-C time delay values for a specific area. This would, of course, be required only once; prior to the beginning of the disposal operation.

Calibration at the channel buoy is only required to insure that the Loran-C receiver has "locked on" to the correct pulse of the Loran signal and is in fact providing accurate position data. If the receiver is not tracking properly, errors will be multiples of 10μsec in time delay which represent significant changes in position. All Loran-C receivers have provisions for sitting the readout to the correct value; therefore, a simple check of the Loran reading when passing the channel buoy will insure proper positioning. Once this has been completed the computer will detect any loss of track and will insure that calibration has been maintained from the harbor to the disposal point.

Once these calibration data are obtained and the disposal points calculated, they are included as part of the software recorded on disk. To operate the system these disks are simply placed in the disk drive unit and the computer, Loran-C and video monitor are turned on. An automatic loading feature then reads the program and associated data from the disk which is then used to record data. After the Loran-C has acquired the necessary stations, the desired disposal point is entered through a special function key and the system is operational. The video monitor will display a grid with the range and bearing to the disposal point.

After the tug has the loaded disposal scow alongside, the ship proceeds out of the channel. As the tug passes, the designated calibration buoy, the inspector checks to insure that the Loran receiver is tracking correctly either by reading the time delay values or pressing a special function key which will compare the present reading with a pre-programmed value. If the Loran time delays are satisfactory the tug proceeds to the disposal site, if not the receiver must be adjusted to provide the correct values.

After leaving the harbor the tug steers directly for the disposal site using the video display and the principle of constant

bearing to approach the dumping point. To accomplish this the helmsman simply steers to make the bearing to the point and the course made good equal (a right turn raises the course made good, a left turn lowers it). This procedure automatically corrects for tidal set, wind drift, compass error, etc. and insures that the point can be approached from any direction. As the tug approaches the disposal point the ship is slowed and once the range to the disposal point is less than a specified amount (in this case, 20m), the scow is dumped. At the time of dumping the inspector presses the special function key to record the location of disposal. This can be done more than once if disposal requires extended periods of time or if additional passes are necessary to dump all pockets in the scow.

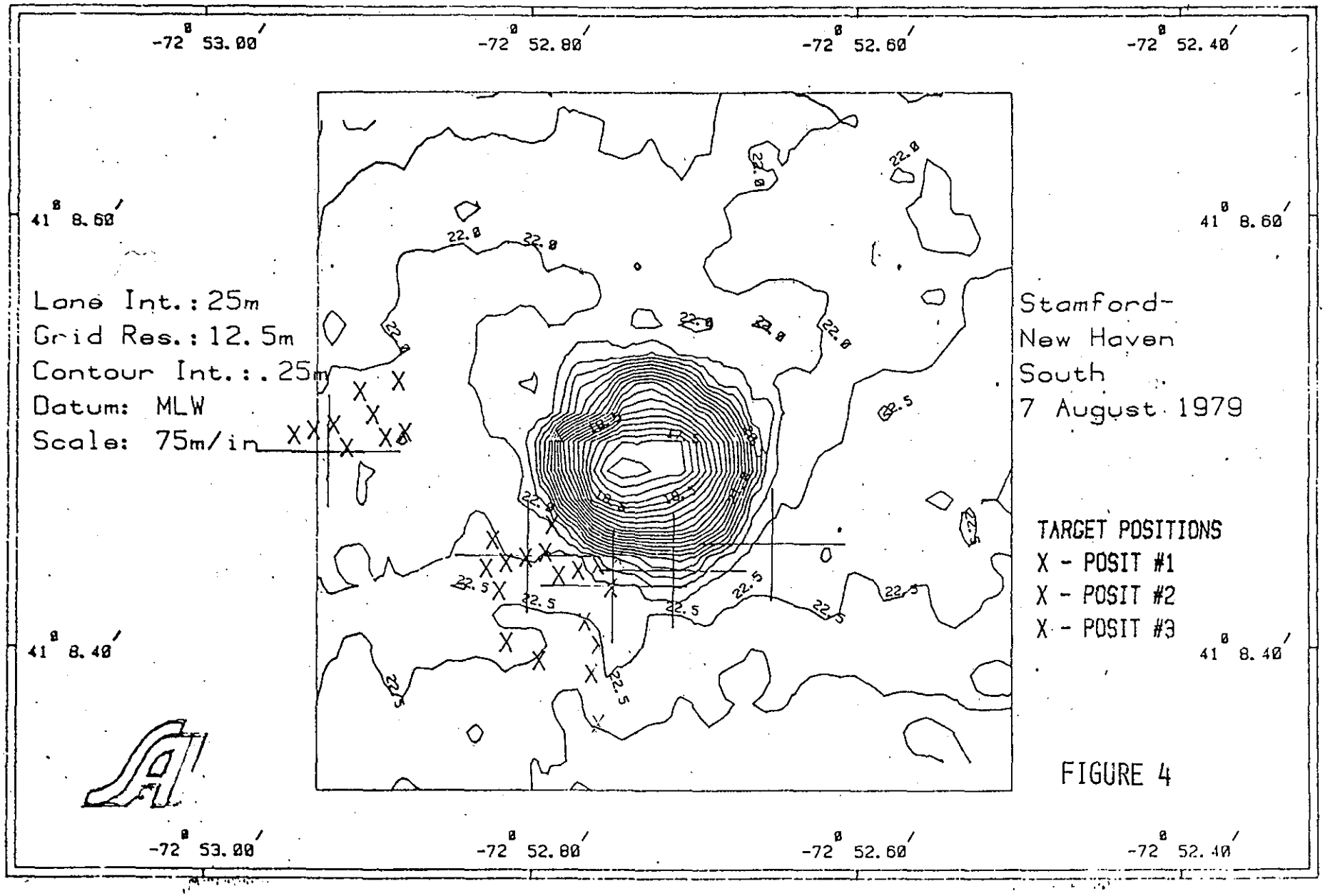
After completion of the disposal operation, the special function key to reverse direction is pressed and the computer provides navigation control back to the calibration point at the harbor entrance. Periodically during the dredging and disposal operations, the disks will have to be changed as they are filled with data, however, this is an extremely simple matter requiring only a temporary reset of the computer.

RESULTS

The SAI Loran-C navigation system was installed on the tug ERNEST M on March 13, 1979 for a period of slightly more than one month. During that time, a total of 35 disposal operations were conducted in the Central Long Island Sound Disposal Site at three designated disposal points in the vicinity of the mound shown in Figure 4. No problems were experienced with the operation of the computer system or the Loran-C receiver in terms of hardware performance; however, initial software incorporated unacceptable time delays in the smoothing functions which caused difficulties in navigation near the disposal point. Once these functions were corrected disposal operations were conducted smoothly for the duration of the project.

Initial problems were also encountered as a result of attempts to use the system beyond the limits of resolution provided by the Loran-C network. Table I presents the results of an analysis of error routine, generated as part of the SAI software package, which provides an estimate of the resolution of the Loran-C lattice at a specified point. For the Central Long Island Sound Site the minimum error (i.e. best resolution) found on the X and Y slaves of the 9960 GRI chain is approximately 30 meters. At the beginning of the project the disposal inspectors were requiring a position within 5 meters of the designated point prior to disposal. Obviously since the precision of the Loran cannot resolve such small offsets, this caused extensive delays in the disposal operation; and when readings of $\pm$ 5 meters were obtained, they were merely coincidental and not representative of actual position. Once the criteria for disposal was relaxed to $\pm$ 20 meters, the operation took place smoothly with no delays.

Figure 4 is a contour chart of the disposal site with the designated disposal points indicated by the large crosses and individual dumping operations indicated by the smaller "x". When considering the distribution of these points relative to the designated location, almost all dumping was accomplished within fifty meters of the desired location. A summary of the disposal locations relative to the designated points is presented in Table II. Although this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41° 8.60′
41° 8.40′
Lone Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 August 1979
TARGET POSITIONS
X - POSIT #1
X - POSIT #2
X - POSIT #3

FIGURE 4

```
LATITUDE = 41 08.756N
LONGITUDE = 72 52.581W

LORAN C TIMES FOR GRI 9960:
  NANTUCKET; MA: 26544.499
  CAROLINA BEACH; NC: 43996.3911

XFORM MATRIX (MICROSEC/MI):
-11.5894905      2.62828306
-2.20944202      8.33967183

INVERSE XFORM MATRIX (METERS/MICROSEC):
-170.014705      53.5808575
-45.0422558      236.266347

LOP VECTORS:
 155 METERS/MICROSEC @ 282 DEG. TRUE
 214 METERS/MICROSEC @ 345 DEG. TRUE

LOP CROSSING ANGLE: 62 DEG.

GDOP POSITIONAL ERROR ELLIPSE
(METERS/0.1 MICROSEC):
  SEMI-MAJOR AXIS: 26.2590347
  SEMI-MINOR AXIS: 14.378042
  BEARING: 118.656085
RESULTANT ERROR
(METERS/0.1 MICROSEC) = 29.9376852

10 MICROSEC. JUMP:
 T1: 1758.80086 METERS
 T2: 2422.65753 METERS
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TABLE I - LORAN-C RESOLUTION

CENTRAL LONG ISLAND SOUND
DISPOSAL SITE

LORAN-C COORDINATES FOR DISPOSAL POINTS

MARCH - APRIL 1980

CENTRAL LONG ISLAND SOUND DISPOSAL SITE

DISPOSAL POINT #1

26543.5	53994.5

DUMP #1

SLAVE X	SLAVE Y
26542.9	43994.7
26543.1	43994.5

DUMP #2

26543.4	43994.5

DUMP #3

26543.3	43994.6

DUMP #4

26543.2	43994.5

DUMP #5

26543.2	43994.7
26544.0	43994.8

DUMP #6

26543.3	43994.6
26543.2	43994.5

DUMP #7

26543.4	43994.5
26544.2	43994.7

DUMP #8

26543.4	43994.7
26543.4	43994.7

DUMP #9

26543.5	43994.6
26543.3	43994.6

DUMP #10

26543.6	43994.6
26543.7	43994.5

DUMP #11

26543.7	43994.6
26543.9	43994.7

DISPOSAL POINT #2

26542.3	43993.9

DUMP #12

SLAVE X	SLAVE Y
26542.1	43993.8
26541.8	43993.4

DUMP #13

26542.2	43994.0
26542.2	43993.6

DUMP #14

26542.2	43993.9
26542.1	43994.0

DUMP #15

26542.5	43993.9
26542.5	43993.9

DUMP #16

26542.1	43993.5

DUMP #17

26542.2	43994.0
26542.1	43993.9

DUMP #18

26542.4	43993.9
26542.4	43994.0

DUMP #19

26542.5	43994.0
26542.6	43994.0

DUMP #20

26542.4	43993.8
26542.4	43993.7

DUMP #21

26542.3	43993.6
26542.5	43994.2

DUMP #22

26542.3	43993.9

DISPOSAL POINT #3

26541.8	43993.7

DUMP #23

SLAVE X	SLAVE Y
26541.8	43993.5
26541.8	43993.5

DUMP #24

26541.9	43993.8
26541.9	43993.8

DUMP #25

26542.0	43993.8
26542.5	43994.4

DUMP #26

26541.9	43993.6
26542.1	43993.6

DUMP #27

26541.7	43993.2
26542.4	43993.3

DUMP #28

26541.8	43993.7
26541.7	43993.6

DUMP #29

26541.8	43993.7
26541.9	43993.7

DUMP #30

26541.8	43993.8
26541.7	43993.6

DUMP #31

26542.0	43993.8
26542.0	43993.7

DUMP #32

26541.9	43993.9
26541.8	43993.8

DUMP #33

26541.8	43993.4
26541.9	43993.1

DUMP #34

26541.9	43993.8
26542.9	43993.8

TABLE II

precision might not be considered accurate enough for placement of contaminated material (depending on the volume), it is certainly adequate for capping and provides a mechanism for controlling the distribution of material without requiring the movement of a disposal buoy.

A bathymetric survey made on April 2, 1980, (Figure 5) gives a clear indication of the development of a small mound west of the main disposal point that was created to cover the Stamford spoil exposed from the errant dump. This mound is emphasized by the box drawn on the chart enclosing the area of coverage.

An unexpected benefit of the Loran system resulted from the procedure of equalizing the course made good with the bearing to the disposal point. Prior to installation of the system, tug operators were required to dead reckon to the disposal area. This was extremely difficult because the compass was nearly useless during transit due to offset of the tug's course to push the scow in a straight line, deviations caused by the mass of material in the scow alongside and corrections required to compensate for current set and wind drift. Consequently, significant time was frequently required to find the disposal buoy, particularly at night or in bad weather. With the SAI computer controlled Loran system the tug was able to steer directly to the disposal point as shown by the course tracks presented in Figure 6. This ability to steer a straight course to the site greatly reduced the time and fuel necessary for a dumping operation during low visibility.

SUMMARY

The use of computer enhanced Loran-C navigation to control disposal operations at the Central Long Island Sound Disposal Site was an extremely successful operation. The ability to distribute material as desired without costly buoy relocation makes this procedure an effective approach to "capping" operations or any disposal operation where a disposal buoy is impractical. Furthermore, the ability to improve the navigation of the tug and scow can save time and fuel during periods of low visibility. Using this procedure, the New England Division has been able to employ effective management

control to cover isolated exposures of contaminated material and to increase the cap thickness on the southern margin of the disposal mound.

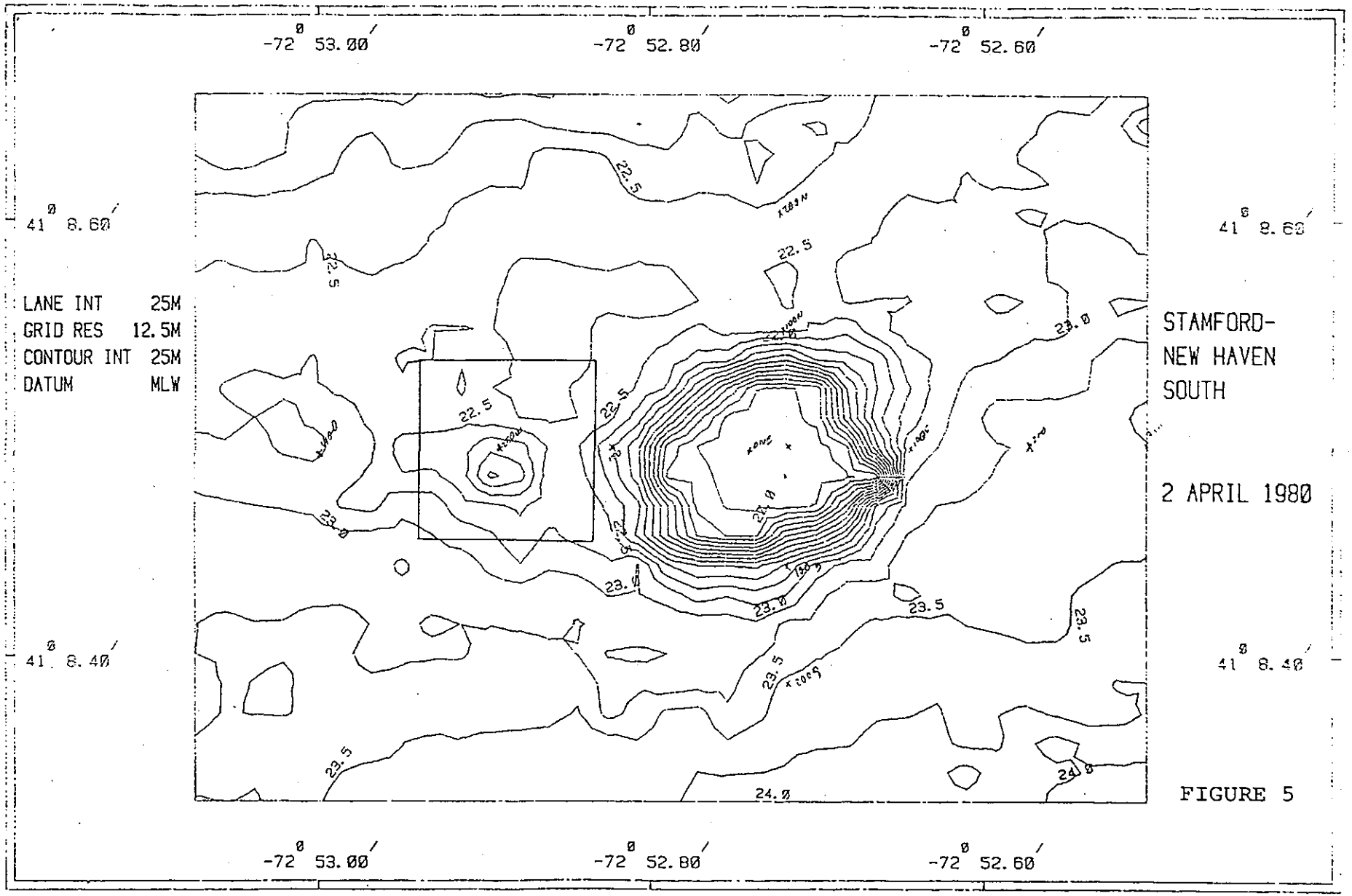
-72° 53.00′
-72° 52.80′
-72° 52.60′
41° 8.60′
41° 8.40′
LANE INT 25M
GRID RES 12.5M
CONTOUR INT 25M
DATUM MLW
22.5
23.0
23.5
24.0
STAMFORD-
NEW HAVEN
SOUTH
2 APRIL 1980

FIGURE 5

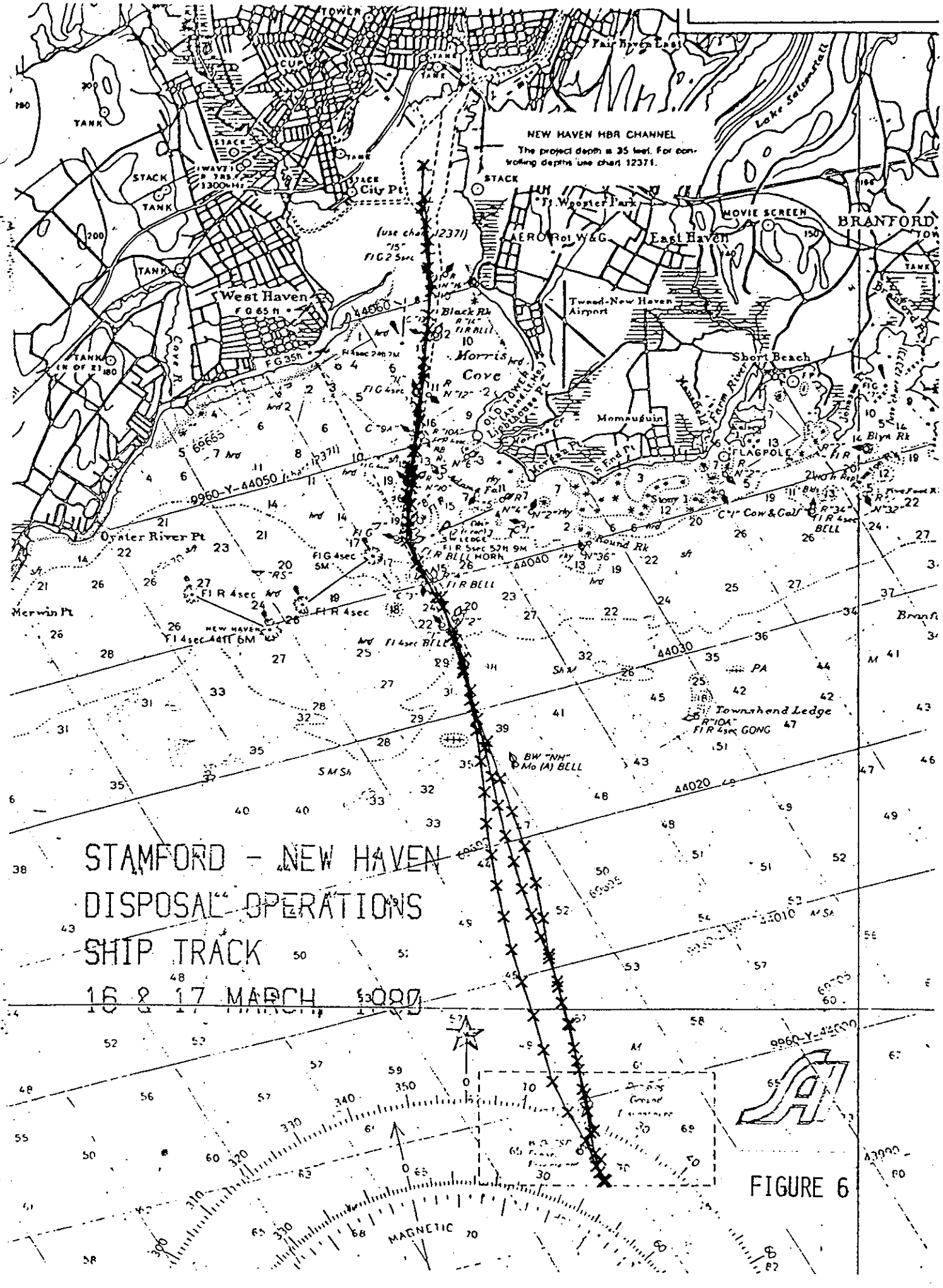
NEW HAVEN HBR CHANNEL
The project depth is 35 feet. For controlling depths use chart 12371.
STAMFORD - NEW HAVEN
DISPOSAL OPERATIONS
SHIP TRACK
16 & 17 MARCH 1988
West Haven
City Pt
East Haven
BRANFORD
Morris Cove
Short Beach
Momauguin
Oyster River Pt
Merwin Pt
Townshend Ledge
Tweed-New Haven Airport
Lake Saltonstall
MAGNETIC

FIGURE 6