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INTERSTATE
ELECTRONICS
CORPORATION
Subsidiary of A-T-O Inc.

NAVIGATION AIDS for OCEAN WASTE DISPOSAL CONTROL

Prepared By
IEC-Oceanics

for the

Ocean Disposal Program
U.S. Environmental Protection Agency

under

Contract 68-01-0796

INTERSTATE
ELECTRONICS
CORPORATION
Subsidiary of ATO Inc.
Environmental Engineering Division
(Formerly OceanicS Division)

REPORT 4460C1629

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NAVIGATION AIDS
FOR
OCEAN WASTE DISPOSAL CONTROL

By

Kenneth W. Herkimer

Prepared for the

U.S. ENVIRONMENTAL PROTECTION AGENCY
OCEAN DISPOSAL PROGRAM
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Prepared by

INTERSTATE ELECTRONICS CORPORATION

Environmental Engineering Division

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ABSTRACT

This monograph is an extract from a comprehensive study on ocean waste disposal which was conducted under contract 68-01-0796 for the Ocean Disposal Program of the Environmental Protection Agency.

As a part of the study the types of navigation aids in existence and in use along the U.S. coastline were reviewed to determine their suitability for use in control of ocean waste disposal operations.

This monograph presents a description and summary of the capabilities of the most prominent systems. A short list of selected current information sources is provided.

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ACKNOWLEDGMENTS

This report is a part of a study that was made possible only through a high degree of cooperation provided by managers, scientists and engineers involved in the the study and control of ocean waste disposal.

A special note of thanks is expressed to Mr. T.A. Wastler, Chief, Ocean Disposal Program, and his scientific and technical staff including in particular, William Musser and BarBara Wygal.

This report was written by Mr. K.W. Herkimer as a part of a comprehensive study of ocean waste disposal in selected geographic areas.

The readers comments and suggestions are solicited and should be addressed to Mr. Sam Kelly, Project Manager.

R.C. Timme
Division Manager

Section 1

INTRODUCTION

In February of 1973, the Environmental Protection Agency undertook a comprehensive study of ocean waste disposal practices in six geographic areas. The purpose of the study was to acquire information to assist the Ocean Disposal Program of the U.S. Environmental Protection Agency in the development of criteria for the control of ocean waste disposal.

During this study, it became apparent that in many cases navigation ability was a significant factor in insuring that material was deposited in the designated disposal area. Some locations such as one shown in Figure 1-1 have visible landmarks that are used for taking bearings in good weather. Other sites, such as one shown in Figure 1-2 are far from shore and require the use of advanced navigation techniques.

As an aid to planners, the available navigation aids for each disposal site authorized in the Federal Register were cataloged. This information was provided in report 4460C1545, An Atlas of Ocean Waste Disposal Sites.

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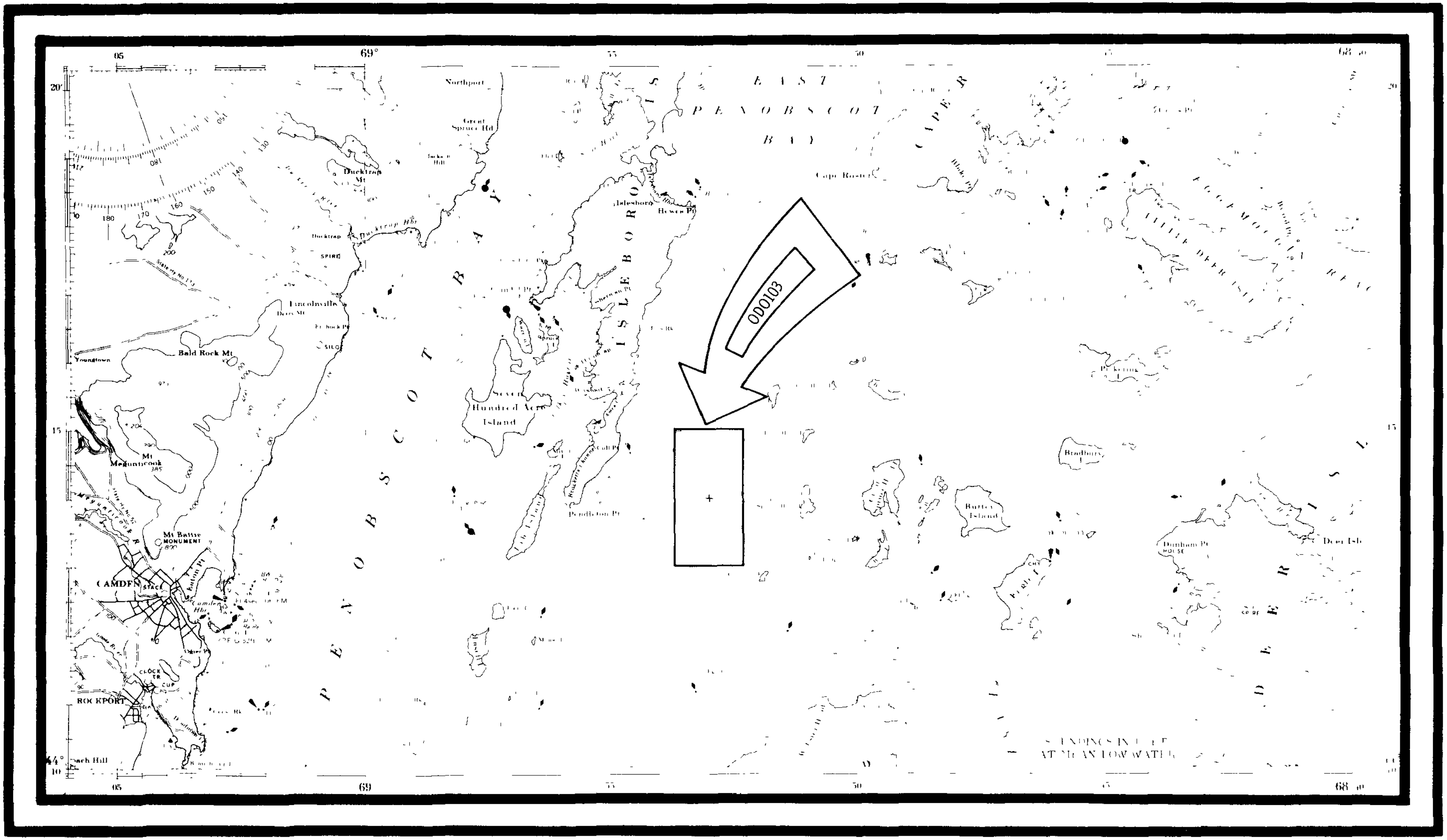
Ocean Disposal Program Office



INTERIM DISPOSAL SITE

September 1973

Center Coordinates	44^{0} 14' 00'' N, 68^{0} 53' 00'' W
Area	2.0 Square Nautical Miles
Navigation Chart No.	NOS 1203
Local Navigation Aids	Decca, Loran A & C, Omega, RDF, Radar
Material Type	Dredge Spoils
Primary Management	COE

SITE NO. 0D0103

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FIGURE 1-1

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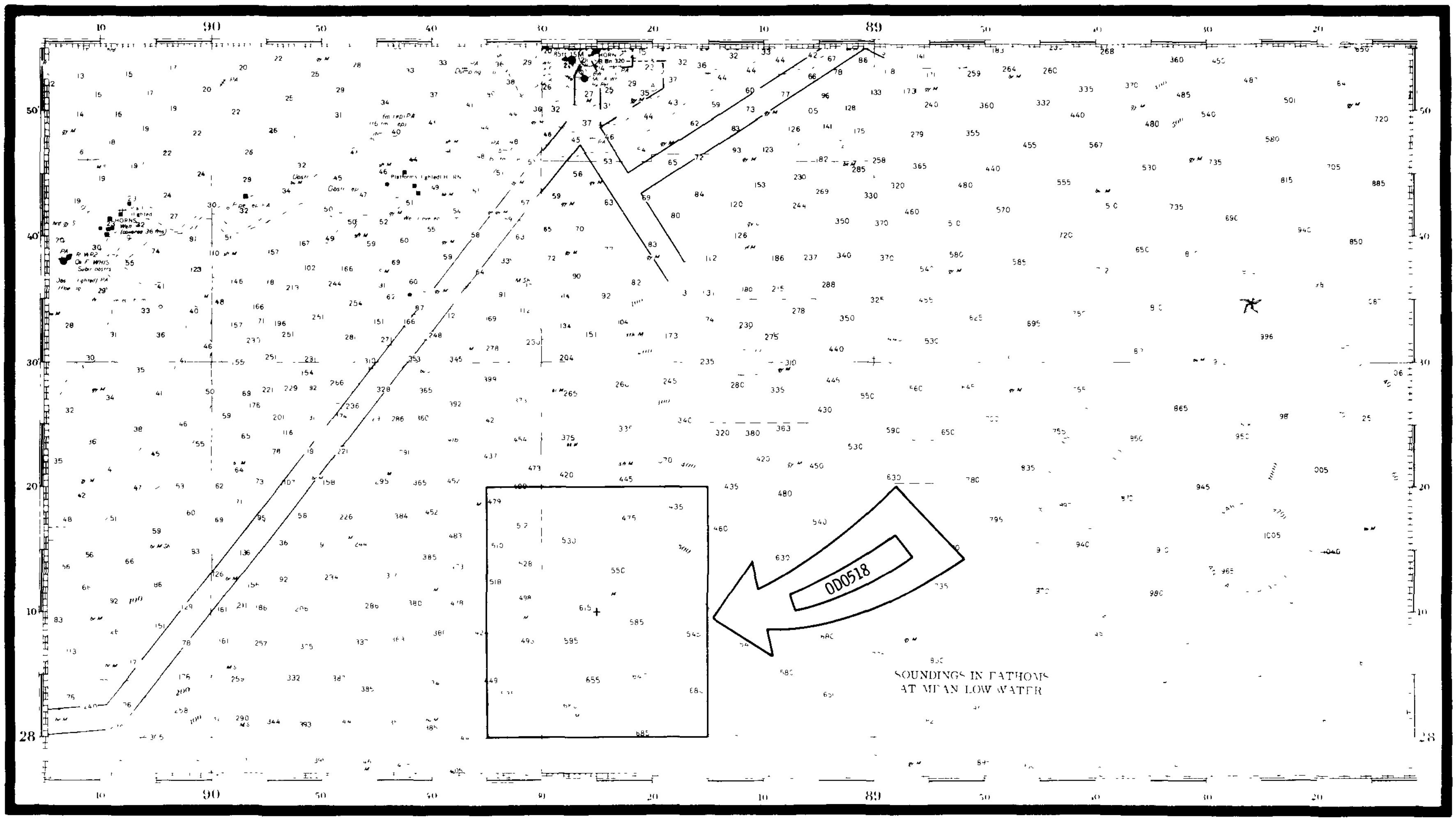

INTERIM DISPOSAL SITE

September 1973

Center Coordinates. . . . . 28^{0} 10' 00'' N, 89^{0} 25' 00'' W
Area. . . . . 352.6 Square Nautical Miles
Navigation Chart No. . . . . NOS 1116
Local Navigation Aids . . . . Loran A & C, Omega
Material Type. . . . . Toxic Chemicals
Primary Management . . . . EPA

SITE NO. 0D0518

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FIGURE 1-2

Section 2

NAVIGATION AIDS FOR OCEAN DISPOSAL VEHICLES

2.1 INTRODUCTION

The majority of the tugs and self-propelled vessels are equipped with various types of navigation equipment, including gyrocompass, radio direction finders, and radar. The long-range tugs have, in addition, Loran A receivers. As a part of this study, an analysis was made of existing electronic navigation aids available on the U.S. coastline. A summary of characteristics and descriptions of these systems is presented in Table 2-1.

The navigation systems discussed in the following paragraphs are systems that are now in existence and in use along the nations' coastlines. The equipments and systems covered herein are presented for the purposes of evaluation in the event that ocean disposal criteria, to include navigation systems, are established.

2.2 LORAN-A

Loran-A is a hyperbolic system of radio navigation available throughout much of the ocean areas of the northern hemisphere.

SYSTEM	LORAN-A	DECCA	LORAN-C	SATELLITE	OMEGA	RAYDIST PASSIVE	CUBIC AUTO TAPE	MOTOROLA RPS	DIFFERENTIAL OMEGA	ONTRAK II RNAV	VTS RADAR
Principle	Pulse	Phase	Pulse & Phase	Phase Doppler	Phase	Phase	Phase	Pulse	Phase	Phase	50 Micro-sec. Pulse
Freq. Band	1900kHz	100kHz	100kHz	150MHz & 400MHz	10.2kHz	1600 - 4000kHz	3000MHz	8000MHz	10.2kHz	10-20 kHz	9.4 GC
Range (N. Miles	600	250	1200	World-wide (Hourly)	World-wide '75	350 Day 175 Night	Radio Line of Sight 50 Mi.	Radio Line of Sight 50 Mi.	3-500 Miles of a shore-based rec'ver	worldwide	to 40 [illegible]
Time for Fix	1-2 Min	Instan-taneously	30 Sec. Indexing	10 Min. (Hourly)	Instan-taneously	Instan-taneously	Instan-taneously	Instan-taneousl	Instan-taneously	Instan-taneousl	Instan-taneously
Sensitivity	500'	50'	50'	60'	400'	1-½'	.1 meter	.1 meter	100'	60'	30'
Accuracy	1-2NM	1/4NM	1/4 NM	100' to 0.1NM	1-2NM	10	50 cm + Range X 10 -5	Soft		1200	.3°
Freedom from Dilution Problems	Medium	Medium	Good	Good	Good	Fair	Good	Good	Good	Best	Good
Probable Maximum Terrain Distortion	40' X Dilution	800' X Dilution	800' X Dilution	Velocity & Orbital Errors 0.1-1NM	10,000 X Dilution	40'	Negligible	Negligible	10,000 X [illegible] Dilution	---------	Negligible
Skywave Error	Negligible	Up to 1 NM (Subtle & not easily forecast)	Negligible (if care-ful)	Negligible	10NM (but generally predict-able to 10%	Negligible (unless obvious)	None	None	X2.5 Miles	Variations stored in Memory-Auto. corrections	NA
Percentage of World Coverage	15%	5%	15%	100% (Hourly)	40% now 100% '72	Special Radio Location Only	Line of Sight	Line of Sight	40% now 100% '75	100	Line of Sight

TABLE 2-1 CHARACTERISTICS OF ELECTRONIC POSITIONING SYSTEMS

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The system employs synchronized pairs of transmitting stations, master and slave, which transmit pulse signals with a constant time interval between them. Loran provides hyperbolic lines of position which are fixed relative to the earth's surface, as are latitude and longitude lines. These lines of position can be crossed with each other or with sun lines, star lines, or other broadcast stations. Special receivers, Loran charts, and tables are required for use of the Loran system. Both ground and skywave signals are used with Loran-A. For the purpose of near shore work, only the ground wave signals will be considered. The range is 650 to 900 miles during the day, and the accuracy is, typically, 1.5 miles over 80 percent of the areas covered. Loran-A is useful on the Atlantic coast, Pacific northwest, Hawaii, and Gulf of Mexico areas. The southwest coast of the United States is limited to a single line of position because of the distance in placement of the slave stations. A second line of position must be taken using an ADF, console, radar, sun, or star sightings. The Loran-A system was scheduled for removal and replacement by Loran-C and Omega by 1975; however, a definite date has not been established and service is likely to continue through 1980.

2.3 LORAN-C

The Loran-C navigation system is a long baseline hyperbolic, area-coverage system, employing time difference measurements of signals received from three transmitters. It is basically a Loran-A system with the following improvements:

a. Low frequency transmission (100 kHz) for extended range.

b. Pulse envelope measurement and phase measurement of the radio frequency signal provide a fine time-difference measurement.

c. Automatic instrumentation aboard the ship can provide a continuous position indication.

d. Higher average transmitting power and phase coding of the multipulse groups allows station identification and discrimination between ground and skywaves.

The ground wave coverage of Loran-C extends to approximately 1200 nautical miles. The accuracy is, typically, 1500 feet over 95 percent of the coverage area. Loran-C may be considered useful on the Atlantic and Gulf coasts, but not on the west coast of the United States. The Coast Guard presently has a budget request of more than $5 million to replace the approximately 30 Loran-A stations with 11 new Loran-C stations and modify six others to cover the continental coastline and southern Alaska. The existing Loran-C system has 8 chains containing a total of 31 transmitting stations. Several of the existing Loran-C stations are located in southeast Asia.

2.4 OMEGA

Omega is a long-range radio navigation system utilizing phase difference measurements of 10.2 kHz carrier frequencies received from each of two stations whose transmissions are phase-synchronized. Hyperbolic lines of position of constant phase difference with the stations lying at the foci of the hyperbolas provide position fix at the intersection of the two lines of position. The accuracy of the fix is proportional to the LOP angles of intersections, 90° being optimum, characteristic of CW phase measuring systems. Cyclic ambiguity causes isophase LOPs or lanes every eight nautical miles. To increase the lane ambiguity these stations cyclically transmit the CW waves at several frequencies i.e., 610.2 kHz, 13.6 kHz, and 11.33 kHz with a 0.2 second off-period between each transmission. With a two-frequency receiver, the resolution or lane ambiguity increases to 24 nautical miles, and with a three frequency receiver improves to 72 nautical miles. Generally, with some minimal dead reckoning navigation equipment aboard the vessel, lane ambiguity is easily resolved. The propagation of Omega signals conforms to the earth/ionosphere wave guide which is a diagonally varying dimension along the propagation path. This variation in ionospheric height produces an effective variation in propagation velocity, which must be compensated for as a function of time and approximate position to assure predictable phase comparison. The variation predictions known as skywave corrections have been tabulated based on a prediction model as a function of time and day for a specific location. Results of measurement programs have shown an operational accuracy of one to two nautical miles rms depending on time of day. Improved accuracy is possible using a Differential Omega approach.

2.5 DIFFERENTIAL OMEGA

In the Differential Omega concept, a remote Omega receiver at a known geographic location is utilized to correct certain unpredictable propagation anomalies thereby resulting in improved fix accuracy. It is assumed that the Omega receiver used for position fixing is experiencing the same unpredictable variations as the remote Omega receiver at the known location and, hence, suitable corrections may be determined and applied to correct the data received by the actual navigation receiver. This approach removes time dependent errors and increases accuracy repeatability to approach the relative accuracy of the two receivers operating in a simultaneous environment. Experimental data obtained with Differential Omega shows an improvement of 4 to 1 over a conventional Omega system with an average LOP error of 4 to 7 centicycles at night and 1 to 3 centicycles during the day (1 centicycle equals approximately 1 microsecond, which is 150 meters on the baseline).

2.6 DECCA

The British-developed Decca system is a hyperbolic radio navigation system which utilizes low-frequency (70-100 kHz) CW transmission signals from a master and three slave stations to provide a position fix. Each station transmits a stable CW frequency signal with a fixed relationship to the frequencies of the other three stations. Phase comparison of the signals produces hyperbolic LOP where the phases are equal. Typical frequencies transmitted would be as follows:

a. Master station 85 (6F)

b. Red slave station 113.333 (8F)

c. Green slave station 127.500 (9F)

d. Purple slave station 70.833 (5F)

These frequencies are multiples of frequency F which in this case is 14.166 kHz. The receiver incoming frequency signals are multiplied by factors to produce frequency differences for the stations which are either 30F (purple), 18F (green), or 24F (red). These differences are measured by a phase meter of the continuously integrating type (deccameter) which indicates total and fractions of cycle that the receiver passes through. Instrument accuracy is on the order of 1 to 50 of a lane corresponding to five yards along the baseline. The Decca system utilizes a lane identification technique for solution of the lane ambiguity problem. Each station transmits, in addition to its fine fixing signal, a lane identification signal by a second transmission at specified intervals. This technique, coupled with a comparison of the F frequency for each of the three phase comparison systems for half a second, reduces lane ambiguity to 1/100 of a lane. Practical coverage for Decca is limited to about 200 nautical miles because of continuous wave propagation and skywave contamination. At this time, a Decca system is in operation on the east coast of the United States. California has proposed the installation of a Decca system on the west coast; however, this has not been finalized. The major drawback of the Decca system is the special receivers required, which must be leased from the British-owned Decca company.

2.7 RADIO DIRECTION FINDING

The use of ground-based radio direction finders for fixed locations has been utilized for many years. In this system, transmissions from the vessels are received at two shore RDF stations from which bearings to the vessel are measured. The two bearings uniquely fix vessel location. The basic principle of direction finding (DF) is the measurement of differential distance to the transmitter using a loop or Adcock type antenna. Currents are generated in each vertical segment of the loop, induced by vertically polarized transmissions, when the loop is 90° to the direction of the arrived signal. Many types of RDF antennas are produced, but the Adcock type is perhaps most attractive for a shorebased RDF station. In its simplest form, this antenna consists of two vertical antennas connected to a receiver. Operation is similar to the loop antenna, the null indicating signal direction. Because of the size of antennas utilized in the 400-kHz to 3-MHz range, physical rotation of the antenna is not practical and a goniometer in conjunction with four or eight antenna towers is used. The goniometer is an instrument consisting of two sets of windings at right angles to each other with a central rotor which, in effect, translates the received radio field at the antennas into a miniature magnetic field in which the rotor operates. The angle output of the goniometer rotor then provides the direction of the transmitted signal. Accuracy of an RDF system depends not only on instrumentation errors, but also on external error factors such as phase interference effects, polarization errors, tilt of the ionospheric layer, and site irregularities. In a modern RDF system, bearing accuracies of ±1° with calibration corrections are possible. At night with skywave contamination the accuracy may vary 2° at 100 nautical miles, and as much as 4° at 500 nautical miles.

2.8 RADAR

Vessel location using a shorebased radar is determined from the time elapsed between transmission and reception of a radar signal (range) and the radar beam antenna directivity (bearing). The operation principles of a radar in its simplest form utilize a transmitter which generates high-power, short-duration pulses which are radiated in a narrow beam by a parabolic reflector which is rotated mechanically or electrically in azimuth. When the pulse strikes the target a small amount of power is radiated back to the antenna and amplified in a receiver. The receiver output is displayed in a pulse position indicator (oscilloscope). The radial scan is generated in synchronism with the transmitted pulse rate and a rotary scan with the azimuth rotational rate. This causes a spot to be illuminated on the PPI scope in which the distance and azimuth are proportional to the true position of the target. When the target is cooperative, a secondary radar (radar beacon transponder) can be used which reduces power requirements of the radar transmitter and reduces clutter by utilizing different frequencies. Modulation techniques can be incorporated on the beacon to provide identification and other coded data. The frequency of radar operation varies depending on range, environment, and accuracy required. Generally, radar range accuracy, which is primarily a function of pulse duration and display resolution, is on the order of 1000 feet, and bearing accuracy, which depends on azimuth beam width, is less than 1°. Because of the high operating frequencies of radar systems, line-of-sight limits range coverage.

Variations of the radar system are the Cubic Auto Tape and the Motorola Range Positioning System (RPS). Both of these systems use a shipboard interrogator and two shorebased transponders. The accuracy of RPS is 50 feet at 50 miles, and the auto tape claims accuracies of 6.4 feet at 30 miles. These systems are limited to line-of-sight, and range in cost between $40,000 and $90,000.

2.9 VESSEL TRAFFIC RADAR

a. San Francisco Vessel Traffic System (VTS). - The Ports and Waterways Safety Act of 1972 (PL 92-340) gives the Department of Transportation the authority for the development, administration, and operation of vessel traffic systems in U.S. ports and harbors. The U.S. Coast Guard is the agency responsible for carrying out this function. The San Francisco Vessel Traffic System is one of the first such systems to be put into service, with eventual coverage of the deep draft waterway system of the San Francisco Port complex, including the bay tributaries extending north and east to Sacramento and Stockton, south to Redwood City, and seaward approximately 20 miles.

The San Francisco system incorporates the functions of the Coast Guard experimental facility formerly known as Harbor Advisory Radar (HAR). The Vessel Traffic Center, operated continuously by Coast Guard personnel, maintains communications with vessels via vhf f-m radiotelephone and monitors the position and movements of larger vessels by shorebased radars and position reports. A traffic separation scheme is now being implemented to separate vessels traveling in opposite or nearly opposite directions. Future developments will include a Coast Guard operated Vessel Movement Reporting System for the Sacramento and San Joaquin Rivers, and a navigational safety summary broadcast, similar to present weather reports, primarily for the benefit of small vessels.

The Vessel Traffic System is a voluntary system of vhf voice communications used in conjunction with a high-resolution radar surveillance system and computer to track traffic in and out of the San Francisco Bay. The system is used out to 8.8 miles, and operation is similar to an air traffic control system. The Coast Guard operator identifies a target on the radar through voice contact; he then enters the data into a computer which stores the information and tracks the vessel through the bay. The primary purpose of the system, is safety. It is a pilot program for several nationwide systems. Presently, Puget Sound maintains a voice-only operation while New York, New Orleans, Houston, Chesapeake, and Delaware are in the planning stages for voice and radar systems. The San Francisco system will use two radars, one at Yorba Buena Island, which would be the "Vessel Traffic Center", the other at Point Bonita. VHF radios will be located at Point Bonita, Concord, and Yorba Buena Island. Radios will operate on vhf f-m Channels 13, 16, 18, and 21. The radar system was designed and supplied by Airborne Instrument Labs with Motorola supplying the microwave inter links. An existing Coast Guard computer will be utilized with special programming by APL, Johns Hopkins. The radars are of a special design for the Coast Guard and feature horizontal, vertical, or circular polarization and digital output. The computer will store seven basic charts of the Bay area, which will be displayed to the operator on 17-inch CRTs for easy identification and tracking. When a ship is logged into the system, it is identified by pilot name, name of the ship, ship registration number, Coast Guard assigned number, and destination. Information is then stored and the ship is tracked to its destination, in port or to sea, automatically. Provision has been made for automatic handoff from radar to radar to the computer. The radar display is photographed every three minutes for permanent records. This system is meant for use with large ships; pleasure craft are not to be included at this time, although the system has sufficient resolution. There are presently no plans for implementing radar transponders aboard the vessels, although it has been considered.

It appears that this system is an excellent candidate for control of offshore dumping out to 20 or 40 miles depending on the elevation of the radar transmitters. The addition of a radar transponder, with auxiliary sensor inputs to indicate the time of dump, would make up a complete monitoring system. This type of transponder is presently under development. Also, since plans are being made to implement this system in New York, New Orleans, Houston, Chesapeake, and

Delaware, the majority of the major dump sites will be covered.

b. Satellite. - The Navy Navigation Satellite System (NNSS) is a worldwide all-weather system from which accurate navigational position fixes can be obtained using the data transmitted from five orbiting satellites, four tracking stations, two injection stations, the U.S. Naval Observatory, and a computing center. Any number of user navigational installations can exist with no interference between them. The navigation satellites are placed in circular polar orbits about earth at an altitude of approximately 600 nautical miles. The orbital planes of the satellites have a common point along the earth's rotational axis. Each satellite orbits the earth approximately every 107 minutes. The geometrical placement of the orbiting satellite allows an earth-bound observer to cross directly under the satellite twice daily. Typically, the observer receives data from the satellite twice each time he is near the orbit, because the satellites appear to traverse longitudinally as the earth rotates. The earth rotates 27° longitudinally per satellite pass. At the equator, about 20 daily fixes are possible. Realistically, about 15 daily fixes can be realized. In Los Angeles (34° latitude) an average of about 29 passes is observed daily, of which approximately 20 provide usable fixes. The utilization of the satellite data to compute a position fix is similar in concept to any hyperbolic positioning system where the satellite simulates the multiple transmitting stations by its inherent motion relative to the user. The shipboard equipment required to use the NNSS consists of an antenna, preamplifier, satellite receiver, computer, and teleprinter. This equipment must be installed in an environmentally controlled area. A position fix using this system permits latitude and longitude on a worldwide, all-weather basis to an accuracy of 40 meters from a single satellite pass. Because satellite passes are available on a 1 to 2 hour interval, dead reckoning between satellite passes, using manual or electrical inputs from the ships speed and heading sensors, is required. A typical shipboard installation of this system will cost between $30,000 and $65,000.

c. Raydist - The Raydist radio navigation system is a proprietary product of the Hastings Raydist Company. Two basic Raydist systems can be considered. They are the DR-S which is an active system utilizing a mobile or shipboard transmitter, and the Raydist T which is a passive system utilizing four shorebased systems. The Raydist system generates dual hyperbolic/hallop coordinate geometries which provide a high degree of operational flexibility and simplicity. A sensitivity of 1.5 feet at a geographic position accuracy of better than 10 feet make Raydist suited to applications ranging from general navigation to precision electronics survey. Presently, only one Raydist system is in continuous operation; it is located in the lower Chesapeake Bay area and provides coverage in the Chesapeake Bay and Virginia continental shelf. This system is sponsored by the State of Virginia. The system is currently under evaluation by several organizations, including the Virginia Marine Resources Commission, Virginia Institute of Marine Science, and the U.S. Coast and Geodetic Survey. The Raydist system can be used out to 150 miles without losing its accuracy. Operationally, a CW signal at approximately 3 MHz is transmitted from the vessel. A reference signal is simultaneously generated at the shore station at a frequency equal to one-half the mobile transmitters carrier frequency, plus or minus 200 Hz. The shore station reference frequency is doubled and heterodyned with the received signal from the mobile transmitter (ship) to obtain an audio beat note of approximately 400 Hz. To obtain red range, the audio tone generated at the red base station is returned to the mobile installation together with the base station reference signal. This is done with minimum use of frequency spectrum by incorporating the audio tone as single sideband modulation on the base station reference carrier. The audio tone information is extracted from the received signal on the vessel, and the base station reference is again doubled and heterodyned with the mobile CW signal within the navigator. This locally generated audio tone has precisely the same frequency as the one derived at the base station, and the two tones exhibit a phase relationship proportional to distance between the vessel and the base station. The two audio tones are then applied to a precision electromechanical phase meter to obtain red range. This process is repeated with the green shore station to obtain the green range coordinate. In the Raydist-T configuration, the CW mobile transmitter is placed ashore, establishing a baseline with respect to the red shore transmitter. For optimum coordinate geometry, a second CW transmitter is positioned to form a baseline with the green base station so the four stations form an approximate rectangle. The resulting independent hyperbolic baselines provide an easy-to-interpret hyperbolic geometry. Three independent lines of position are available from the four-station arrangement, providing a convenient means for automatic or manual lane identification. This feature can be used for lane determination by ships approaching outside the coverage area. The Raydist signals are completely continuous and tracking response can be made extremely fast permitting the systems use in high performance aircraft and rapidly maneuvering vessels with negligible accuracy degradation. The major drawback of this system is the limited number of installations in the U.S. This system, however, is available for lease anywhere in the world.

d. VLF Area Navigation Ontrac II is the trade name of a receiving/computing (RNAV) system manufactured by Communications Components Corporation of Costa Mesa, California, which uses existing vlf navigation and communication transmitters providing worldwide navigation. The basic principle of operation is that all vlf stations are phase stable and can be used to generate hyperbolic lines of position, which the built-in computer converts to latitude/longitude. Unlike

Omega, which utilizes phase-synchronized transmitters, this system measures the phase difference at the beginning of a run and stores the information in memory. Six receivers are operated simultaneously, allowing automatic selection of the best three signals. A built-in minicomputer looks at the phase difference (arrival times) and displays the changes in latitude/longitude and speed as the vessel is underway.

To use the system, the operator must enter (through a small keyboard) his point of departure latitude/longitude in degrees, minutes, and seconds; date; time; destination latitude/longitude; and any way-points he may desire. The unit then displays latitude/longitude of his present position; heading and distance to destinations (five way points); speed and time to destination; time (GMT); and left/right track. All of these displays are available as external outputs. Special tables and charts are not required to operate this system to its stated accuracy of 1200 feet. Another feature of this device is a dead-reckoning mode. Because the device has its own computer and memory, it is able to remember its last position and, in the event of a complete loss of signal, will continue to compute heading, position, and speed based on its last known inputs.

At the time of this writing, the system is just going into production. Its prime purpose is the replacement of inertial navigation in small jet aircraft.

The selling price of the system is estimated to be under $20K. The unit is small in size, operates from 24 VDC, and requires no special installation. From present information, this system is a strong candidate for navigation/control of the dumping vessels.

2.10 SUMMARY

In brief summary, the existing level of documentary monitoring of operational practices of ocean disposal is inadequate for the number and scope of disposal operations.

In connection with regulatory monitoring, present inspection of disposal operations is inadequate. To correct this situation, an improvement in monitoring by means of an automatic, tamper-proof vessel log similar to that used by airlines and trucking firms should be considered.

NAVIGATION AIDS

The synthesis and evaluation of candidate automatic regulatory dump monitoring systems requires a comprehensive understanding of present operational dumping practices and detailed information and characteristics of electronic navigation techniques as well as of the dump vessels themselves, including vessel berth locations, speed, range, dump control specifics, and communication equipments. Additional factors to be considered include dump vessel traffic, type of dump material, existing shore facilities and personnel, and owner/captain cooperation.

An operational automatic vessel monitoring system must rely heavily on existing electronic navigation systems because it must integrate this position information with other events such as time of day, time of dump, duration of dump, and water depth.

Section 3

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AN ATLAS OF OCEAN WASTE DISPOSAL SITES
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