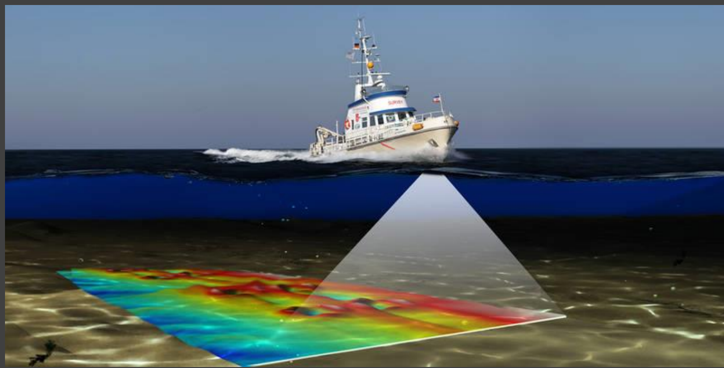


Comprehensive Guide to Hydrographic Surveying

Credits: 5 PDH

Course Description

Hydrography is the science of measuring and describing the topographical features and the entire aquatic environment as a whole, beneath the surface of water bodies. These subsurface features affect bridge scour, flood mitigation, erosion control and siltation transport, maritime navigation, marine construction, dredging, offshore oil exploration and offshore oil drilling, among many other activities.

Hydrographic surveying does not strictly apply to coastal and oceanic regions of the US. Hydrographic surveying has many applications inland. Many environmental and civil engineering project in and around bodies and channels of water (streams and rivers, lakes and ponds, wetlands) can all benefit from hydrographic surveys and analysis.

Topics

- Intro and overview of hydrographic surveying
- History and early methods of measurement
- Sounding poles, lead lines, wire drags
- Echo sounders and fathometers
- Agencies which perform hydrographic surveys: office of coast survey, NOAA, USGS, COE, IHO, NOO
- Marine magnetometry
- DC resistivity imaging
- Radar altimetry
- GPR for marine applications
- SONAR devices: side scan, single beam, multi beam sonar
- Light Pulse (LIDAR) devices
- US maritime limits and boundaries
- Sources of existing bathymetric datasets
- Types of tidal datums (sounding and chart) and tidal cycles
- AUV, ROV and UAS technologies
- Crowdsourced bathymetric surveying
- Fisheries acoustics

Online-PDH
1265 San Juan Dr.
Merritt island, FL 32952

Original Courseware by:
Donald W. Parnell, PE

Chapter 1: Introduction

Page 1: Hydrographic Surveying

What is Hydrography?

Hydrography is a branch of physical oceanography or applied science which deals with the measuring and description of the configuration of the bottoms and adjacent land areas of oceans, lakes, rivers, harbors, and other water forms.

What are Hydrographic Surveys?

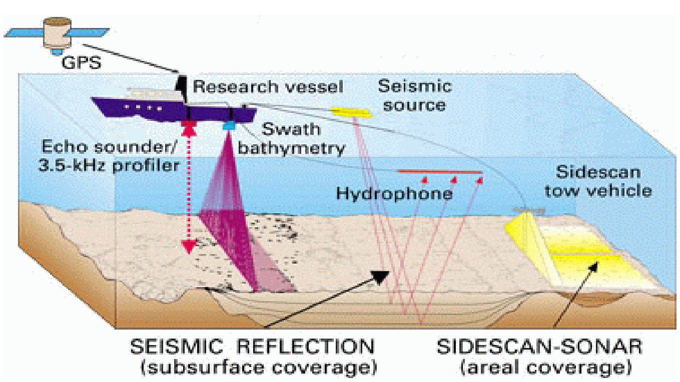
A hydrographic survey deals with measuring and description of features of a water area and the bed configuration; however, it may also encompass a wide variety of other objectives such as the measuring of tides, currents, gravity, Earth magnetism, and for determining the physical and chemical properties of water.

Bathymetric Surveying

The label of hydrographic surveying is often synonymously applied to bathymetric surveying. However, the latter actually refers to the study and measurement of the bottom or "bed" of a navigable water body (whether it is an ocean, river, lake or other body or channel of water.) In other words it deals with the topography of the solid earth, beneath a body of water.

> **Bathymetry**
>
> The term "bathymetry," originally nautical in origin, referred to the ocean's depth relative to the sea level (free surface), although it has since come to refer to the "submarine topography," or the depths and shapes of the underwater earthen terrain.

Below are various types of hydrographic surveying methods.



Hydrographic Surveys for Safe Navigation

There are numerous reasons to conduct a hydrographic survey, but the most common objective is for compiling nautical data along navigational channels, with an emphasis on the measurement and profiling of the subsurface physical features that may affect safe navigation and travel by marine vessels.

The image above shows a dredging operation consisting of a clamshell bucket dredge on a barge

Documenting the Geomorphic Changes

Routine hydrographic surveys are essential to documenting the transportation of silt and sedimentation, in order to unsure safe lanes of shipping in rivers and along coastlines.

Natural currents and storm events such as hurricanes tends to shift the silt on the sea or river beds, potentially accumulating in previously dredged channels, causing dangerous conditions or obstructions.

Locating Submerged Obstacles

In addition to the surveying of geomorphic changes, hydrographic surveys may be utilized to locate submerged vessels and other hazardous debris along river and sea beds.

A hydrographic survey can be used to facilitate offshore oil and gas exploration, drilling operations, marine construction, dredging, installation of subsea cables and more.

Other Applications

Other applications for hydrographic surveying:

- to generate the data needed to create and update nautical charts

- to verify that navigational channels are clear and accurate
- port and harbor maintenance (dredging), expansion, and re-design
- coastal engineering and geomorphological evaluations
- beach erosion and replenishment studies
- coastal zone management
- offshore resources development
- oil and gas exploration
- volumetric studies
- erosion and siltation studies
- pre- and post-dredge evaluations
- river crossing profiles and evaluations
- aquatic vegetation design
- flood studies
- to locate and verify the integrity of submerged cabling and piping
- for determining fisheries habitat and understanding marine geologic processes
- to determine seabed and riverbed materials (i.e. sand, mud, rock)
- preliminary bed analysis for anchoring, construction of marine structures, and pipeline and cable routing
- disaster response following storm events; looking for changes in depth or debris in navigational channels

Page 3: History of Hydrographic Surveying

Origins

The history of hydrographic and bathymetric surveying likely dates back to the origins of sailing. As long as people have sailed the oceans, there has been the need to chart pathways for safe travel to avoid vessel groundings, and to document regional and seasonal oceanic currents and meteorological patterns.

US Coast Survey

Establishment of the US Coast Survey – 1807
In the US, the first officially sanctioned hydrographic surveying office began in 1807, with the establishment of the "US Coast Survey", which is one of the oldest scientific agencies in the US. This agency was established when then President, Thomas Jefferson and Congress authorized a survey to be taken of coasts of the newly formed "United States of America."

First Head of the US Coast Survey

The first person to officially head the US Coast Survey was Ferdinand Rudolph Hassler, who assembled a number of skilled professionals from various scientific communities, to survey and chart out the coastlines of the US.

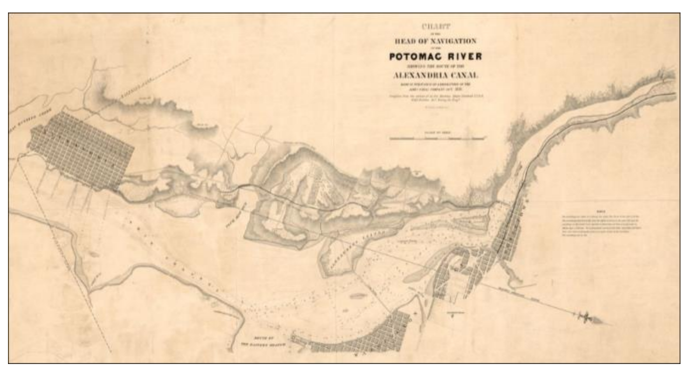
> **Types of Professionals at the USCS**
>
> - mathematicians
> - cartographers
> - geodesists
> - meteorologists
> - hydrographers
> - topographers
> - sailors and laborers
> - administrators

The first official US survey - 1834

The first official hydrographic survey performed in the US was conducted along the southern shore of Long Island in 1834.

The first official US nautical chart – 1839

In 1839, the US government produced its first nautical chart. However, many privately commissioned charts of the Americas were known to exist prior to this date.



Navigational chart of the Potomac estuary (created in 1838 by the Alex'a Canal Company)

Page 4: Early Hydrographic Surveying Methods – Sounding Poles and Lead Lines

Prior to 1900s – Poles and Lines

Shallow water surveys – In early hydrographic practice, shallow water surveys consisted of depth measurements conducted by use of sounding poles.

Deep water surveys – Sounding Lines

In greater depths, a sounding line (or lead line) was used to make measurements of river channel, estuarial and oceanic navigational pathways. Positions were determined by three-point sextant fixes to mapped reference points. A more sophisticated means of measuring deep water at this time was through the use of sounding machines, which were simply reel or drum based line devices.

Sounding poles

A sounding pole (see image below) is simply a long rod, (usually made of wood, or aluminum in present day use), that is used to measure navigational channel depths. Though mainly used to measure water depth, they may be used to measure the depths of boreholes, snow piles, or loose soil stockpiles as well.

A typical length of a sounding pole is about 20 feet, marked in one inch increments. They might have a circular plate at one end to ensure that the location being measured is somewhat level and normalized, and to prevent inaccuracies due to the pole sinking too deep into the muck or silt bottom. The pole technician would drop the pole until there is adequate resistance at the soil bed, and then a measurement is taken at that depth. Multiple drops are made within close proximity to verify that a consistent reading was taken.

Though rudimentary equipment such as sounding poles have since been replaced by SONAR, LIDAR and other bathymetric methodologies, they are still sold by some survey supply companies, and may be used in areas where large amounts of vegetation or thick mud would tend to distort the electronic returns of modern equipment.

> **"Mark Twain"**
> In modern literature, Samuel Clemens took his pen name from his early employment as a leadsman on the Mississippi River. The leadsman was the person who used a sounding pole or lead line to measure the river depths to ensure the boat was staying away from the shallow banks. To "mark twain" referred to marking a depth of the water of two fathoms, or 12 feet.

Lead Lines

Lead line systems consisted of ropes or lines, with depth markings and lead weights attached (see image). The lead weights were usually conical in shape, weighing around 12-14 lbs., and occasionally had a small amount of wax or lard on the base to collect a small sample of the surface sedimentary deposits. This rudimentary but effective system could reportedly provide reliable soil samples to depths of 100 fathoms or 600 ft.

The line was lowered until it hit bottom, then read manually in a tedious, painstaking process. These initial depth soundings were fairly accurate.

> **The "Fathom"**
> In the early days of hydrographic surveying, a fathom was used to measure water depth. A fathom is a linear unit of measurement, equal to 6 feet.

However due to the time involved per reading, there were a limited number of sounding measurements relative to the area being surveyed, which inevitably left gaps in coverage between the individual soundings.

Sounding Machines

Several sounding machines were patented in the late 19th century, using reels or drums with a

handle, to deploy the wire and measure output. Fashioned after the lead line method of depth measurement, they were invented out of a need to increase the accuracy and speed of deeper water soundings.

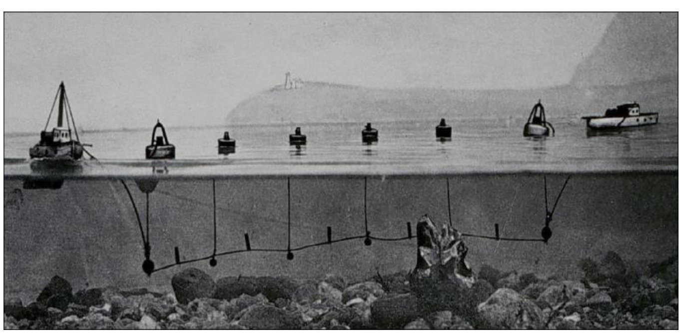
Accumulators

The heave effects on the sounding lines were compensated for, by devices called “accumulators.” They were attached at intervals along the length of the sounding line and could stretch up to lengths of 17 feet, with a maximum exertion of 70 pounds force, in order to somewhat equalize the strain and prevent snapping of the line due to vessel roll, bottom snags, or other abrupt motions.

Page 5: Early Methods – Wire Drag Surveys

1900s - Weighted Wire-drag Surveys

In 1904, the weighted wire-drag method (see image below) of surveying was implemented, whereas a wire would be attached in between two vessels, and dragged between the two points.



The wire was set at a given depth using a system of weights and buoys. When this rig encountered an obstruction, it would become tight, forming a "V" shape, thus revealing the depth and position of submerged rocks and other obstructions. The wire drag system was the most reliable means of detecting and recording the location of submerged obstacles at the time. Wire drag data was used mainly to supplement the existing hydrographic survey data used when preparing navigational charts.

This system was used for a good part of the 20th century, until electronic and acoustic technologies arrived that allowed a single ship to do the same work as two wire-drag vessels, using side-scan sonar or multibeam sonar.

Wire Drag Operation

The wire drag operation operated at a speed of around 2 knots. Each vessel was independently controlled to maintain position along a pre-plotted course. One of the vessels, the “guide ship,” maintained a planned speed along the course without regard to its position relative to the sister vessel. The sister vessel would adjust its position, to remain abeam of the guide ship, speeding up or slowing down slightly as needed.

The buoys which suspend the drag wire were under constant observation for any “hang,” (which was an indication of a submerged object.) When a hang occurred, it was necessary to determine as accurately as possible the coordinates of the obstacle, be it a wreck, shoal, or other form of debris.

Location of the hang was determined by recording the locations of each vessel and the bearing of each vessel to the apex of the “V” which marked the location of the hang. Scuba divers were then dispatched to swim along the ground wire until the snag was located. The obstruction was then investigated and its exact depth measured by divers using a lead line.

Use of Sister Ships

There were a limited number of ships which specifically performed these wire drag operations for the US Coast and Geodetic Survey, and later NOAA. Until the late 80’s these ships were commissioned jointly as “sister ships”.

Marindin and Ogden

From 1919 to 1942, the USC&GS Marindin and USC&GS Ogden conducted wire-drag surveys as a joint operation.

Hilgard and Wainwright

From 1942 to 1967, the USC&GS employed two ships, the Hilgard and her sister ship the Wainwright, which conducted wire-drag hydrographic survey operations together along the US East Coast until 1967, when they were then replaced by the USC&GS Rude (ASV90, and S590) and Heck (ASV91, and S591).

Research ships of this type were known as auxiliary survey vessels or “ASV” while under the authority of the USC&GS, then later to be designated as survey vessels or “S”, following the 1970 change of agency, falling under the new authority of NOAA.

Heck and Rude

Commissioned in 1967, the Heck and her sister ship the Rude, (see image below) like the previous paired vessels, were specifically designed for conducting wire-drag survey operations. These ships worked together under a single command conducting wire-drag surveys, clearing large swaths between them with a submerged wire.

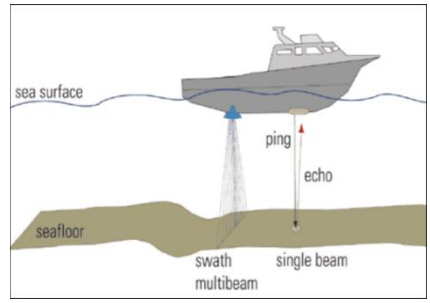
During their commissions, however, electronic and acoustic technologies were developed that allowed a single ship to perform the same work as two wire-drag vessels, using side-scan sonar or multi-beam sonar.

As a result, Heck and Rude began to operate independently in 1989, employing this improved technology, thus ending the days of these wire drag pairings.

Page 6: Early Methods – Echo Sounders and Fathometers

1930s - Single beam echo sounders and fathometers

In the 1930s, single-beam echo sounder systems were developed and subsequently implemented for use in hydrographic surveying practice. Echo sounding was based on technological concepts published in 1904 by Norwegian Inventor Hans Sundt Berggraf, and patented by German inventor Alexander Behm, in 1913. These devices used sound to measure the distance to the sea floor directly beneath a survey vessel.



By running a series of lines at a specified spacing, single beam echo sounders and fathometers greatly increased the speed of the surveying process by allowing a greater number of data points to be collected. Even so, this method still left gaps in the quantitative depth data in between the survey lines.

In addition to single beam echo sounder devices, there are echo sounders that are capable of receiving multiple return "pings". These systems known as multi-beam echo sounders are covered in depth in chapter 4 of this course.

Fathometers

From the combination of “fathom” and “meter,” fathometers were a type of echo sounder. In 1925, the Submarine Signal Company of Boston developed the first fathometer, under the product title “312 fathometer,” for charting the water depth while a ship was moving.

The fathometer proved to be more precise and easier to use than previous sounding methods, making it an essential device for hydrographic surveying, and safer navigation in some uncharted regions.

These 312 Fathometers displayed deep-water depth soundings with a continuously rotating white light. The fathometer technician would read depth measurements by monitoring the position of the light when an echo was heard in a set of headphones.

The 312 Fathometer differed from previous systems, in that it could still be operated while the survey ship was moving. This technique was eventually improved upon with a red light method, where a rotating neon tube flashed adjacent to the depth scale when the echo returned.

Dorset Fathometer with Transceiver

In 1933, the Dorsey fathometer was developed, which incorporated a transmitter plus a receiver into a singular unit which came to be known as a "transceiver". The Dorsey fathometer had an operating range of 3 to 900 feet, and by 1939, could record depths automatically, using a graph-recording instrument.

Other Improvements in Fathometers

In 1940, the portable 808 fathometer was released, which was equipped with a graphic recording device. This became the standard device for shallow to intermediate surveying until the mid-60's.

In the mid-60s, with the advent of digital technology, computerized data collection systems for hydrographic surveying equipment became the standard. In the 70's, the accuracy of echo sounding devices were increased with the development of single-beam frequency systems, and by the 80's, were enhanced by the deployment of dual frequency beams.

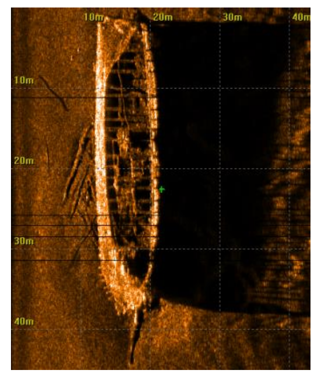
These systems combined a narrow high-frequency beam for precision, and a wider low-frequency beam to provide broader sampling of the surrounding area.

Page 7: Modern Day Hydrographic Survey Methods

Modern Tools for Hydrographic Surveying

A number of revolutionary technologies have been advanced in the latter half of the 20th century that changed the fundamentals of hydrographic surveying, and how we view the seafloor.

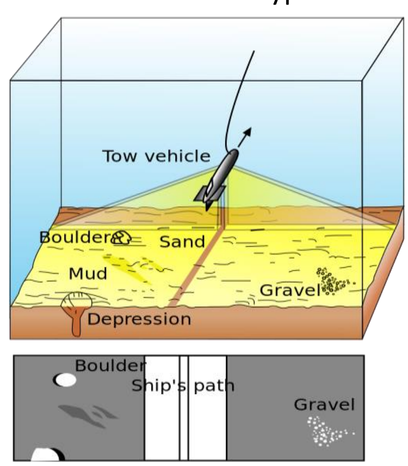
New technologies such as side scan sonar offered a means of obtaining high quality underwater imaging, improving the ability to identify long lost, submerged shipwrecks (see image below), or viewing subtle obstructions and protrusions.



Other new marine surveying technologies include: single and multibeam sonar, LIDAR, Magnetometry, DC Resistive Imaging, radar altimetry, and ground penetrating radar. These topics will be discussed in further detail in chapters 3 and 4 of this course.

Side Scan SONAR

Side scan sonar is a type of sonar imaging device that efficiently and clearly creates an image of large regions of the sea bed. (The image to the left) show a diagram of a side scan sonar's potential imaging path. This type of sonar system will be discussed in depth, later in this course.

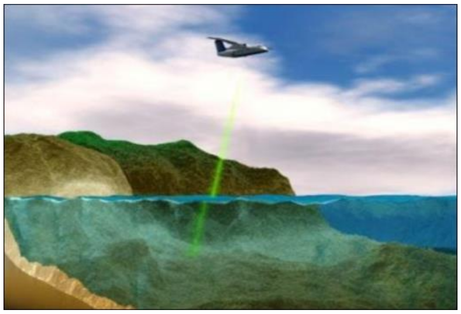


LIDAR

LIDAR (or Light Detection And Ranging) technology, measures the elevation or depth by analyzing the pulses of laser light reflecting off an object. LIDAR survey systems which perform bathymetric surveys are usually mounted on aircraft and provide seamless, contiguous coverage between land and sea.

Bathymetric LIDAR

This can be used to acquire imaging in areas with complex and rugged shorelines where surface vessels cannot operate efficiently or safely because of rocks, kelp or breaking surf. Some of the inhospitable areas include Alaska, the North Atlantic Coast and the Caribbean Isles. LIDAR systems will be covered in more depth, later in this course, as well.



Marine Magnetometry

Marine magnetometry surveys are performed using a specially modified magnetometer which is housed within a tow-behind shell known as a towfish.

The magnetometer is dragged behind the vessel using a tether line which doubles as a data transmission cable. Magnetometers come in a variety of designs, used for a variety of specialized applications.

Marine DC Resistive Imaging

Direct current (DC) electrical resistivity is a geophysical surveying technique that has a long track record for characterizing subsurface conditions.

Marine electrical resistivity imaging (ERI) has the precision capabilities of DC electrical resistivity methods, combined with the data collection speed of traditional EM techniques. By towing an electrode array behind a survey vessel and continuously recording data, the marine resistivity system can record many times the line distance of a traditional electrical resistivity land system.

Applications include characterizing sediment types, identifying zones of underwater groundwater seep and discharge, as well as the mapping of geological structures.

Georadar

(GPR) Ground penetrating radar or “georadar” is a geophysics seismic method based on the use of focused radar energy which penetrates the ground to image subsurface conditions.

This system can only be used in fresh water applications and is not suited for use in brackish or saltwater environments.

Satellite-based Radar Altimetry

Satellite measurements of sea floor features are based on gravitational bulges in sea surface caused by underwater topography change. The surface of the ocean bulges outward and inward representing the topography of the ocean floor.

The bumps, too small to be seen, can be measured accurately by a radar altimeter aboard a satellite. Satellites are also used to measure bathymetry. Satellite radar maps deep-sea topography by detecting the subtle variations in sea level caused by the gravitational pull of undersea mountains, ridges, and other masses.

On average, sea level is higher over mountains and ridges than over abyssal plains and trenches.

Chapter 2: Official Agencies of Hydrographic Surveying

Page 1: The International Hydrographic Organization (IHO)

The International Hydrographic Organization (IHO)

Consisting of a collaboration of roughly 87 countries, the IHO is the inter-governmental organization which represents hydrographic interests throughout the globe.

A primary goal of the IHO is to ensure that the world's seas, oceans and other significant navigable water regions are adequately surveyed and charted. The IHO establishes international sets of standards for hydrographic surveying, and coordinates the efforts of the various national hydrographic survey offices.

Observer Status at the UN

The IHO has "observer status" at the United Nations, which means it has non-member privileges, giving them the ability to participate in the UN's activities.

The IHO is the principally recognized authority on hydrographic surveying and nautical charting within the United Nations. When referring to hydrography and nautical charting in Conventions and similar Instruments, it is the IHO standards and specifications that are typically referenced.

History of the IHO

The IHO was first established in 1921, as the International Hydrographic Bureau (IHB). In 1970 the present title of IHO was adopted as part of a new international "Convention on the IHO."

Throughout the 19th century, a number of maritime nations established individual hydrographic agencies as a way of improving the navigational abilities of naval and merchant vessels, by providing nautical publications, charts, and other navigational services. However, there were considerable differences in hydrographic procedures, charts, and publications. In 1889, an International Maritime Conference was held, proposing the establishment of a "permanent international commission."

Similar proposals were suggested at the sessions of the International Congress of Navigation in 1908, and the International Maritime Conference in 1912. In 1919, hydrographers from England and France collaborated, taking the necessary steps to convene an international conference of hydrographers selecting London as the most suitable locale for the conference.

1919 Conference

In July of 1919, the First International Conference opened, attended by the hydrographers of 24 nations. The objective of the conference, which still stands today, was:

"To consider the advisability of all maritime nations adopting similar methods in preparation, construction, and production of their charts and all hydrographic publications; of rendering the results in the most convenient form to enable them to be readily used; of instituting a prompt system of mutual exchange of hydrographic information between all countries; and of providing an opportunity to consultations and discussions to be carried out on hydrographic subjects generally by the hydrographic experts of the world."

As a result of this 1919 Conference, the permanent organization was formed and statutes for its operations were prepared.

Page 2: Office of Coast Survey

US Coast Survey

The "US Coast Survey" was the official title of the governmental agency tasked with creating nautical charts for the US. Established in 1807 by Thomas Jefferson, it is among the oldest scientific organizations still in operation within the US government.

In 1878, the name was changed to that of the "US Coast and Geodetic Survey (C&GS)," and later, in

1970 it was transferred, as an organizational sub branch of the National Oceanic and Atmospheric Administration (NOAA,) under the title of "The Office of Coast Survey," which remains as the official name.

Background

In 1807, acting President Thomas Jefferson signed the document entitled "An act to provide for surveying the coasts of the United States." While the bill's objective was specific, to produce nautical charts, it reflected larger issues of concern to the new nation, being national boundaries, commerce, and defense.

The early years of this agency were unsteady, and struggled for a stable direction. Ferdinand Rudolph Hassler, who was to eventually become the Coast Survey's first superintendent, traveled to England for the purpose of acquiring scientific instrumentation. However, he was prevented from returning throughout the duration of the War of 1812.

> **Ferdinand Rudolph Hassler**
> Ferdinand Hassler was appointed the superintendent of the Survey in 1832, and served in that position until his death in 1843. Originally from Switzerland, he was a surveyor who worked predominantly in the US, heading the US Coast Survey and the Bureau of Weights and Measures (under the US Treasury Dept.)

Following his return, he began work on a survey of the New York Harbor in 1817. But before the survey could be completed, the US Congress intervened, suspending the work due to tensions between civilian and military control of the agency, eventually falling under the control of the US Army.

After a number of years under military authority, the Survey of the Coast was reestablished in 1832, with acting President Andrew Jackson appointing Hassler as superintendent.

The U.S. Coast Survey continued as a civilian agency with military personnel and vessels of the Navy and Army being detailed to service with the Survey. For the most part, army personnel worked on land-based topographic surveying and mapping, while naval personnel worked on hydrographic surveying in coastal waters.

1970 to present – as a NOAA agency

In 1970, Richard Nixon formed the still operational National Oceanic and Atmospheric Administration. The Coast and Geodetic Survey (C&GS) was subsequently brought into this new scientific oceanographic agency.

Today, the "Office of Coast Survey" provides the nation with navigation products and information for improving commerce and security, and for protecting coastal environments.

The "Office of Coast Survey, NOAA" conducts hydrographic surveys to measure the depth and bottom configuration of water bodies, using the data to update nautical charts, create GIS layers, and to develop hydrographic modeling.

Increasingly, this hydrographic data is being used for a multitude of uses, through the Integrated Ocean and Coast Mapping program.

Page 3: National Oceanic and Atmospheric Administration (NOAA)

ESSA

In 1965, the Environmental Science Services Administration (ESSA), was established and became the new parent organization of both the Coast and Geodetic Survey and the US Weather Bureau.

In the process, the Coast and Geodetic Survey Corps was removed from the Survey's direct control, and put under the subordination of ESSA, and renamed the Environmental Science Services Administration Corps, or "ESSA Corps." As the ESSA Corps, it still had the responsibility for providing commissioned officers to man Coast and Geodetic Survey ships.

NOAA

In 1970, ESSA was expanded and reorganized to form the National Oceanic and

Atmospheric Administration (NOAA). The Coast and Geodetic Survey became defunct, as it merged with other governmental scientific agencies to form NOAA; however its constituent parts lived on within other agencies.

The geodetic responsibilities were reassigned to the newly formed “National Geodetic Survey,” its hydrographic survey duties to NOAA's new “Office of Coast Survey,” and its ships to the new NOAA fleet, while the ESSA Corps became the new National Oceanic and Atmospheric Administration Commissioned Officer Corps, or "NOAA Corps".

The National Geodetic Survey, Office of Coast Survey, and NOAA fleet all fell under control of NOAA's new National Ocean Service.

Roles of NOAA

NOAA plays several specific roles in society, the benefits of which extend beyond the US economy and into the larger global community:

1) As a Supplier of Environmental Information Products

NOAA supplies information to its customers and partners pertaining to the state of the oceans and the atmosphere.

This is clearly manifest in the production of weather warnings and forecasts through the National Weather Service, but NOAA's information products extend to climate, ecosystems, and commerce as well.

2) As a Provider of Environmental Stewardship Services

NOAA is also the steward of U.S. coastal and marine environments. In coordination with federal, state, local, tribal, and international authorities, NOAA manages the use of these environments, regulating fisheries and marine sanctuaries as well as protecting threatened and endangered marine species.

3) As a Leader in Applied Scientific Research

NOAA is intended to be a source of accurate and objective scientific information in the four particular areas of national and global importance identified above: ecosystems, climate, weather and water, and commerce and transportation.

Five Fundamental Activities of NOAA:

- Monitoring and observing Earth systems with instruments and data collection networks.
- Understanding and describing Earth systems through research and analysis of that data.
- Assessing and predicting the changes of these systems over time.
- Engaging, advising, and informing the public and partner organizations with important information.
- Managing resources for the betterment of society, economy and environment

Page 4: US Naval Oceanographic Office

Depot of Charts and Instruments

In 1830, the US Navy established the “Depot of Charts and Instruments” to maintain a supply of nautical charts for issue to naval vessels. It soon became apparent that the Depot would be unable to obtain and maintain an adequate supply of the latest data unless it undertook production of charts from its own surveys.

In 1837, the first survey sponsored by the Depot and led by Lieutenant Charles Wilkes resulted in four engraved charts published for use by the US Navy. Lieutenant Wilkes continued his surveying and gained fame as leader of the U.S. Exploring Expedition.

The expedition ranged over the eastern Atlantic to Antarctica, the coasts of both Americas, and far into the west and southwest Pacific. It began the U.S. collection of world magnetic data and contributed substantially to hydrographic, meteorological, botanical and geological knowledge of the explored regions.

Over the next five years, 87 similar charts were published and issued from the results of surveys by Wilkes and his officers. These individual surveys, however, were limited in scope; the Depot needed a way to gather information quickly on a worldwide basis.

Matthew Fontaine Maury

Naval officer Matthew Fontaine Maury, who became known as "The Pathfinder of the Seas", supplied the answer to this dilemma. Commander Maury, who held the position of Hydrographer of the Navy from 1842-1861, is credited with founding the science of oceanography. His system for collecting and using oceanographic data revolutionized navigation of the seas.

Maury assuming command of the office in 1842 recognized the possibilities for expanding the services of the Depot. He suggested the creation of a central agency, so that hydrographic data could be digested, compiled and published for the benefit of all.

This idea became the basic formula of hydrographic offices throughout the world, making Maury's contributions a milestone in naval oceanography. Within five years, 26 million reports poured into the Depot, which originally had been intended only as a storehouse of charts and instruments.

US Naval Observatory and Hydrographical Office
In 1854, the agency was given the official name of The US Naval Observatory and Hydrographical Office. In 1866, an Act of Congress separated the two functions, establishing the Hydrographic Office as a distinct activity.

By this time the Office's mission had expanded to include "the carrying out of surveys, the collection of information and the printing of every kind of nautical chart or publication." The Office continued to grow throughout the nineteenth century.

Surveying Ice Hazards

The collision of the Titanic with an iceberg in 1912 prompted the Hydrographic Office to urge that an ice patrol be established to document sea-ice hazards to prevent such disasters.

This was the beginning of our present day's sophisticated, high-tech methods of surveying, measuring and recording of ice thickness, ice-ridge profiles and other characteristics to monitor ocean-ice conditions above and below the surface.

Advent of Sonic Sounding Methodology

Because features and conditions of the world's oceans are constantly changing, surveying, charting and mapping must be continuous processed. Experiences during World War I showed the need for a greater level of accuracy for oceanographic data.

By 1922, responding to these needs, the Navy had developed the first practical sonic sounding machine, making it possible to surpass all previous efforts in deep-sea sounding and bathymetric charting. Aerial photography was used for the first time that year.

WWII Era Hydrographic Surveying

Following the attack on Pearl Harbor, the demands for charts increased to about 40 times that of the pre-war rate.

The Hydrographic Office was moved to more adequate facilities at Suitland, Maryland, about 6 miles from the nation's Capital building, and was placed under the cognizance of the Chief of Naval Operations to focus activities directly to programs of national security.

Additional survey vessels were obtained, each equipped to conduct surveys and to produce printed charts aboard ship in a minimum of time to keep up with fleet advances across the Pacific. At the peak of World War II, 43 million charts were printed and issued in one year.

Present day Location and Title

The Hydrographic Office was redesignated as the US Naval Oceanographic Office (NAVOCEANO) in 1962, and in 1976 the Office was relocated to the National Space Technology Laboratory (NSTL), which is now known as the John C. Stennis Space Center, in southern Mississippi.

NAVOCEANO still oversees the Naval Ice Center in Suitland, Maryland, and the Fleet Survey Team at Stennis Space Center, Mississippi, and is the largest subordinate command under the parent agency (CNMOC) or "Commander, Naval Meteorology and Oceanography Command," which is also located at Stennis Space Center.

Page 5: US Geological Survey - National Hydrography Dataset (NHD)

No Bathymetric Data

Though the NHD does not specifically contain the bathymetric or underwater topographic profile data for the nation's waterways, it does contain the boundaries of these water bodies and channels.

The National Hydrography Dataset (NHD)

The NHD is a digital database which consists of surface water features used in mapping applications.

It contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages. Cartographers can link to or download the NHD to use within their own computer mapping software. The NHD can be used in mapping, or can also be used to perform geospatial analysis within GIS applications.

It is a digital vector-based geospatial dataset designed for use in analyzing the flow of water throughout the nation, representing over 7.5-million miles of streams and rivers and 6.5-million lake and ponds.

Use in GIS Applications

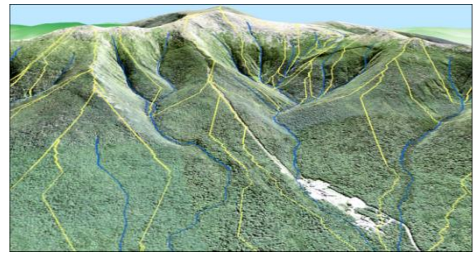
In mapping, the NHD is used with other types of data themes such as elevational, boundary, or transportation features to produce general reference maps.

In geospatial analysis, the NHD can be utilized by a variety of different GIS specialists and scientists which use GIS technology for their geospatial analysis and modeling.

Analyzing water flow using directional attributes

The NHD can take advantage of a flow direction network that can be processed to trace the flow of water downstream.

A rich set of attributes used to identify the water features includes an identifier, the official name of the feature, the length or area of the feature, and metadata describing the source of the data.



This image shows a digital terrain map, overlain with hydrological features.

The identifier is used in an addressing system to link specific information about the water such as water discharge, water quality, and fish population.

Using the basic water features, flow network, linked information, and other characteristics, it is possible to study cause and affect relationships, such as how a source of poor water quality upstream might affect a fish population downstream.

The National Map

The NHD is part of the USGS's "The National Map Project," which is the collaboration between the USGS and other federal, state, or local agencies to improve and deliver topographic information of the US.

The NHD is also linked with similar datasets which represent the surface waters of Canada and Mexico. The dataset primarily maps features a 1:24,000-scale, but in certain areas provides detail at 1:5,000-scale.

Some of the GIS thematic features which are available in the National Map project are:

- Hydrography
- Roadway Infrastructure
- Structures
- Ortho-imagery

- Topography
- 3D elevations
- Historical Features
- Land cover

NHDPlus

A version of the NHD, called the "NHDPlus," is integrated with elevational and other landscape data to create detailed drainage catchments and flow volume and velocity estimates for streams and rivers of the US at 1:100,000-scale. This data is available from the EPA agency.

Page 6: US Army Corps of Engineers and the Intercoastal Waterway System

USACE

The US Army Corps of Engineers (USACE) is the largest supplier of nautical chart update data for NOAA. USACE is the governmental agency which is responsible for developing the nation's inland waterways for commercial navigational use.

The USACE is tasked with the operation and maintenance of roughly 12,000 miles of navigational channels and 230 locks, and are responsible for surveying much of the US inland waterways and ship channels, including the Intercoastal Waterway Systems.

Projects overseen by the USACE:

- waterway channels (roughly 12,000 miles)
- anchorages
- turning basins
- lock systems (230)
- dams
- protective jetties
- breakwaters
- The Intercoastal Waterway System
- US Port System (926 federal harbor channel projects that support the US port system)

USACE Districts

Approximately 25 USACE districts located throughout the country provide NOAA with charting information. NOAA relies exclusively on the USACE to provide this survey and tabular information concerning the US Port System, and associated harbor channels. Each district maintains their own database of survey sheets; select a location and district to find files available for download.

US Port System

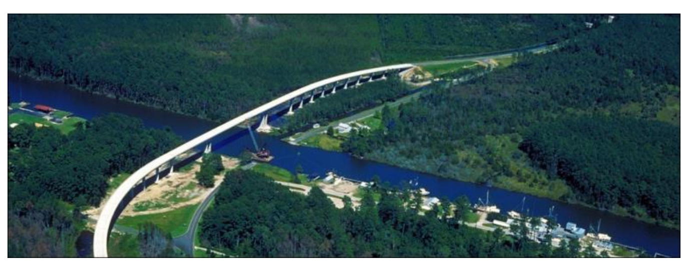
The U.S. deep-water port system includes more than 300 federal harbor channel projects. There are 51 ports with depths greater than or equal to 40 feet.

Federal channels are the main arteries of our nation's waterways, and it is imperative that accurate depth and position data remains up to date and accurate. Ports do not only exist in seacoast cities, but exist in a number of deep inland cities as well, such as St. Paul and St. Louis, Kansas City, and Louisville, to name a few.

Major rivers such as the Mississippi, Ohio, James, Delaware, Arkansas, Verdigris, Illinois, Columbia, Snake, Hudson, and the Great Lakes regions all have ports which are maintained by the USACE. In addition, there are a number of USACE ports situated in the various bays, sounds, canals, and inlets throughout the US.

The Intracoastal Waterway

The Intracoastal Waterway (ICW) is a 3,000-mile inland waterway along the Atlantic and Gulf of Mexico coasts of the US, running from Boston, Massachusetts, southward along the Atlantic Seaboard and around the southern tip of Florida, then following the Gulf Coast to Brownsville, Texas. Some sections of the waterway consist of natural inlets, saltwater rivers, bays, and sounds, while others are artificial canals.



The ICW provides a safe, well-maintained navigable route along its length without many of the navigational hazards of travel found on the open sea.

Page 7: Non-official, Privately Funded Surveys

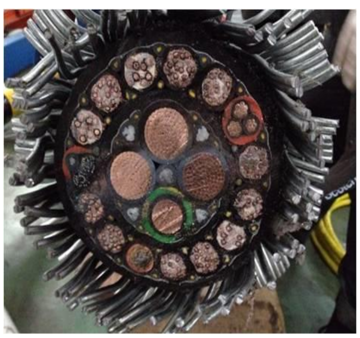
Surveys by the Oil Industry

Governmental agencies are not the only parties which conduct hydrographic surveys. Many commercial entities also conduct large-scale hydrographic and geophysical survey ventures; especially in the oil exploration, and offshore drilling industries.

Surveys for Submarine Cabling

Industrial entities installing submarine communications cables or power lines require detailed surveys of cable routes prior to installation.

They increasingly use acoustic imagery equipment previously found only in military applications when conducting their highly specialized marine surveys.



Specialized companies exist that have both the equipment and expertise to contract with both commercial and governmental entities to perform such surveys.

The above image shows a cross section of a subsea cable cluster.

Private Funding of Projects

Large construction companies, universities, and investment groups will often fund hydrographic surveys of public waterways prior to developing areas in the proximity of navigable waterways.

Private surveying firms are also contracted to survey in support of design and engineering firms that are under contract for large public projects.

> **The "average area end" method**
> This is typically used to approximate the volume of sedimentary material to be removed by dredging. This method assumes that the volume quantity between adjacent sections is linear and does not account for irregularities.

Dredging Operations

Private surveys are also conducted prior to and following most dredging operations to obtain volumetric readings before and after the sediment is removed.

Private Harbors and Waterfront Facilities

Companies with large private slips, docks, or other waterfront installations have their facilities and the open water near their facilities surveyed regularly; particularly following any major storm events.

Page 8: Crowdsourced Bathymetric Surveying

Crowdsourcing

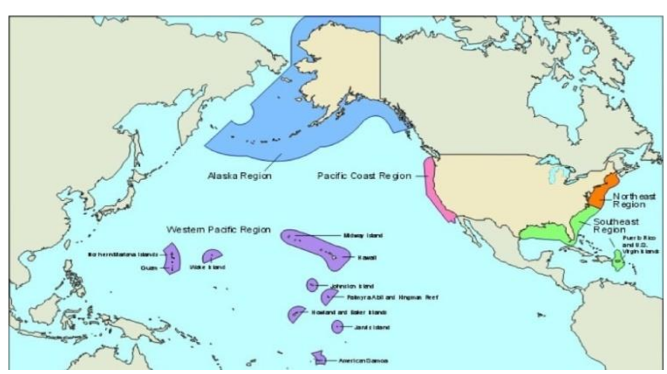
This means of private funding is entering the hydrographic surveying arena as well. Publicly funded projects such as OpenSeaMap, TeamSurv and ARGUS, are some examples of these public collaborations.

Outdated Sounding Data

Nearly half of the sounding data which is shown on US NOAA nautical charts dates back to pre-1940. This data was collected by antiquated lead line soundings and wire drag operations. Even the 500,000 square nautical miles of the most navigationally significant EEZ waters would require 167 years to survey.

EEZ

The (EEZ) or exclusive economic zone is the zone



where the US and other coastal nations have jurisdiction over natural resources, (see image below.)

Augmenting existing Geodata

Crowdsourced data can significantly augment authoritative geodata bases and provide answers to critical mapping deficiencies. The challenge in the marine geospatial sector is to ensure the reliability of crowdsourced data by managing and structuring the process to ensure that it can be confidently relied upon as useable and accurate.

OpenSeaMap

This is a software project collecting freely usable nautical information and geospatial data to create a worldwide nautical chart.

TeamSurv

This is a collaborative effort to gather GPS and depth data from small craft in order to fill in data gaps in existing datasets.

ARGUS

This is similar to the TeamSurv effort, which seeks to augment the existing bathymetric datasets with small vessel volunteer collaboration.

Volunteer Crowdsourced Surveying

Volunteer crowdsourced vessels record position, depth, and time data using standard navigation instruments, and then the data is post-processed to account for speed of sound, tidal, and other corrections.

With this approach there is no need for a specific survey vessel, or for professionally qualified surveyors to be on board, as the expertise is in the data processing that occurs following the raw data upload to the server.

Crowdsourcing has the benefit of greatly reduced, or free surveying providing a continuous survey of an area, however some of the drawbacks include the effort and time involved in recruiting participants, and in acquiring a high enough density and quality of data.

Although these collaborative surveys are normally accurate to 0.1 - 0.2 meters, this approach is no valid substitute for a professional and systematic survey. Nevertheless, the results are often more than sufficient to meet many requirements where high resolution, high accuracy surveying is not necessary or affordable.

Chapter 3: Acoustical (Sound) Based Techniques and Equipment

Page 1: Echo Sounding and SONAR

SONAR

Sonar (which was originally an acronym for SOund Navigation And Ranging) is a technique that uses sound propagation in a water medium, to navigate, communicate with or detect objects on or beneath the surface of the water, such as rocks, shoals, or other vessels.

Active and Passive Sonar

Two forms of sound technology share the name "sonar": passive sonar is essentially listening for the sound made by vessels; active sonar is emitting pulses of sounds and listening for echoes.

Sonar may be used as a means to acoustically locate or measure the echo characteristics of "targets" in the water.

Air-based Sonar

Acoustic location in air was used before the development of radar wave technology. Sonar may be used in air for robotics navigation, and SODAR (upward looking in-air sonar) is used for atmospheric investigations. The term sonar is also used for the equipment used to generate and receive the sound.

Hydroacoustics

The acoustic frequencies used in sonar systems vary from very low (infrasonic) to extremely high (ultrasonic). The study of underwater sound is known as underwater acoustics or hydroacoustics.

Echo Sounding

Echo sounding is a type of sonar which is used for determining the depth of a body of water by transmitting sound pulses into water. The distance is measured by multiplying half of the time, (from the signal's outgoing pulse to its return after reflecting from a solid surface,) by the speed of sound in the water. For precise applications of echo-sounding, such as hydrographic applications, the speed of sound must also be measured through means, such as deploying a sound velocity probe into the water.

Higher Accuracy

Most charted ocean depths use an average or standard sound speed. Where greater accuracy is required average and even seasonal standards may be applied to ocean regions.

For high accuracy depths, usually restricted to special purpose or scientific surveys, a sensor may be lowered to measure the temperature, pressure and salinity.

These factors have subtle effects on sound propagation, and are used in calculations to fine tune the actual sound speed in the local water column.

Fathometers

Echo sounding is effectively a special purpose application of sonar used to locate the bottom. In the past, prior to present day depth measurement units, a unit of water depth was the fathom. Thus early echo sounding devices or instrumentation used for determining water depth was referred to, as a fathometer (see image above).

Hydro Acoustic Assessments

Echo sounding can also refer to hydro acoustic "echo sounders" defined as active sound in water (sonar) used to study fish.

Hydro acoustic assessments have traditionally employed mobile surveys from boats to evaluate fish biomass and spatial distributions. Conversely, fixed-location techniques use stationary transducers to monitor passing fish.

"Sounding"

The term "sounding" refers to all types of depth measurements, including those that don't use sound, and is unrelated in origin to the word sound in the sense of noise or tones.

Page 2: SONAR for Hydrographic Surveying

Considerations

In areas where detailed bathymetry is necessary, a precise echo sounder may be used for the work of hydrography. There are a number of variables to consider when evaluating such an echo sounding system.

Considerations such as:

- vertical accuracy
- resolution
- acoustic beam width of the transmitting or receiving beam
- the acoustic frequency of the transducer

Dual Frequency

Most hydrographic echo sounders are dual frequency, having a low frequency pulse (which is typically around 24 kHz) that can be transmitted simultaneously with a high frequency pulse (typically around 200 kHz).

Since both frequencies are discrete, (as opposed to continuous) the two return signals do not typically interfere with one another.

Advantages

There are many advantages of dual frequency echo sounding, including the ability to identify a vegetative layer or a layer of soft silt or muck on top of a layer of rock. Most hydrographic operations use a 200 kHz transducer, which is suitable for inshore work up to 100 meters in depth.

Use of Lower Frequencies

Lower frequencies required for deeper soundings
Deeper water requires a lower frequency transducer than shallower waters, as the acoustic signal of these lower frequencies is less susceptible to attenuation (a reduction in the amplitude of the signal) in the water column. Commonly used frequencies for deep water sounding are 33 kHz and 24 kHz.

Narrow beam width for deeper soundings
The beam width of the transducer is also a consideration for the hydrographic surveyor.

In order to obtain the best resolution of the data which is captured, a narrow beam width is preferred. This is especially important when sounding in deep water, as the resulting footprint of the acoustic pulse can be a very wide swath once it reaches the distant sea floor.

Multibeam Sounders

In addition to the single beam echo sounder, there are echo sounders that are capable of receiving multiple "return pings". These systems are discussed in further detail on page 4.

Standards

Standards for hydrographic echo sounding
The required precision and accuracy of a hydrographic echo sounding is defined by the requirements of the International Hydrographic Organization (IHO) for surveys that are to be undertaken to IHO standards.

These values are contained within the IHO publication S44. In order to comply with these standards, the surveyor needs to take into consideration, the vertical and horizontal accuracy of the echo sounder and transducer, as well as the survey system as a whole.

Different hydrographic organizations, such as NOAA for example, will have their own sets of field procedures and operations manuals, to guide their surveyors in meeting the required standards.

Page 3: Side Scan Sonar

Side Scan Sonar

This is a type of sonar system that is very efficient at clearly imaging large areas of the sea floor. A Side Scan Sonar is able to provide a near photographic imaging of the sea's bottom, allowing for a clear and concise evaluation of the subsurface conditions. This provides a clear picture of the bottom of the scanned area, showing major obstructions and protrusions, cabling piping and mechanical infrastructure, and other objects such as shipwrecks.

Most side scan systems provide clear imaging but cannot provide depth information. Like other types of sonar devices, a side scan type transmits pulsed sound energy in the form of a fan and analyzes the return signal (echo) that has bounced off the seafloor or other solid surfaces.

In a side scan, the fan of transmitted energy sweeps the seafloor from directly beneath the towfish to either side, typically to a distance of 100 meters. The strength of the return echo is continuously recorded, creating a "picture" of the ocean bottom and solid surfaces which the scan encounters.

Objects that protrude from the bottom create a light area (strong return) and shadows from these objects are dark areas (little or no return), or vice versa, depending on operator preference.

Side scan sonar is typically used in conjunction with a single beam or multibeam sonar system to meet full bottom coverage specifications for hydrographic surveys. For instance, NOAA field units normally use various models of side scan sonar in both hull-mounted and towed configurations.

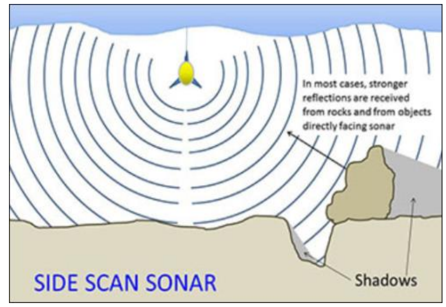
The intensity of the acoustic reflections from the seafloor of this fan-shaped beam is recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an image of the sea bottom within the swath (coverage width) of the beam.

The sound frequencies used in side-scan sonar usually range from 100 to 500 kHz; higher frequencies yield better resolution but less range.

SSS Towfish

The Side Scan Sonar (SSS) Tow Fish contains the transmitting circuitry to energize transducers, which project high intensity, high frequency bursts of acoustic energy in the fan-shaped beams, which are narrow in the horizontal plane and wide in the vertical plane. These sound beams project along the sea bed on both sides of the moving vessel.

Objects or topographic features on the seabed produce echoes, which are received by the transducers.



Echoes are received and amplified and sent up the Tow cable to the Graphic Recorder located on a ship. The data is also tape recorded for future post-processing.

The system has widespread applications on oceans, inland lakes, rivers, harbors and canals.

The SSS method is used for a number of different submarine applications, such as:

- geological studies
- sand ripple studies
- bathymetry & hydrography
- mineral search
- cable and pipeline locating (SSS for exposed and SBP for buried)
- Various types of marine construction and engineering surveys
- Dredging
- wreck location and general searching
- underwater archaeology
- gas seeps
- military applications
- iceberg scour mapping
- fisheries applications
- etc.

The basic components of the system consist of:

- Side Scan Sonar Tow Fish
- Towing Cable
- Graphic Recorder

GLORIA Side Scan Sonar

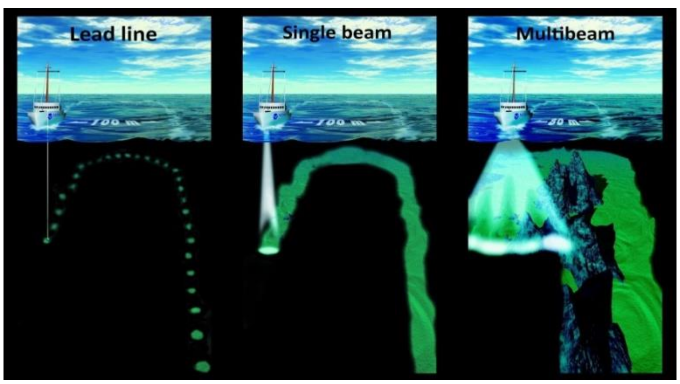
The GLORIA side scan sonar is another type of side scan sonar system used for determining the topography of the ocean floor. GLORIA stands for "Geological Long Range Inclined Asdic." Like most side-scan sonars, the GLORIA instrument is towed behind a ship.

This type of sonar operates at relatively low frequencies to obtain long range scans, and is used for surveying large areas. GLORIA has a ping rate of two per minute, and detects returns from a range of up to 22 km on either side of the sonar fish.

Page 4: Single Beam and Multi Beam Sonar

Single Beam vs Multi Beam

When choosing between various depth sounding, hydrographic survey approaches, there are several factors that a hydrographic surveyor must consider, with pros and cons in each type of surveying system.



The image above shows a comparison of the coverage with lead line (non-sonar), single beam sonar and multi beam sonar surveys

Single Beam

A single beam system provides a less expensive, simpler technique, providing faster processing and results. Single-beam depth sounding (both single and dual frequency systems) can only capture a profile directly beneath the transducer, and are run on lines, or "transects" at approximately 90 degrees to the underwater slopes.

They are typically separated by between 25 and 50 feet in docks and harbors, and between 100 and 2000 feet in navigation channels.

Multi Beam

A multi beam system is a more complex and advanced technology than single beam. They are a appropriate choice for a variety of different projects, including construction, dredging, and engineering. An advantage of these systems is that they provide 100% bottom coverage and are able to complete a scan of a given area much quicker.

The larger the project area and the deeper the water, the more advantageous this method will become, as the reduced time on the field more than compensates for the higher daily cost of operation.

Pros of Multi Beam

Most end users of the data will value the greater density of multi beam depth measurements, the increased resolution of smaller features, and the ability to view upslope areas, or beneath docks and ships. The quality of the datasets which are created, and the methods of displaying the results, show more detail and are often easier to comprehend.

Cons of Multi Beam

On the other hand, the equipment is more difficult to use and understand. Also in very shallow waters, the multi-beam system will become nothing more than an expensive single beam system, because the swath width reduces to nearly the same coverage width as a single beam.

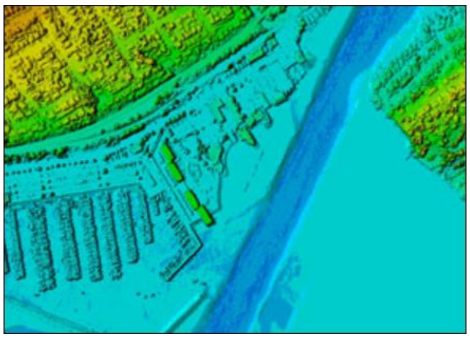
Although, with the multi-beam system, high spots and even some objects that would normally be missed in a single beam survey, can easily be detect.

Chapter 4: Other Hydrographic Surveying Methods

Page 1: LIDAR

LIDAR

Provides seamless land and sea coverage
LIDAR (light detection and ranging) technology measures elevation or depth by analyzing the



reflected pulses of laser light off an object. Lidar-based surveying systems are usually mounted on aircraft and are capable of providing seamless, contiguous coverage between land and sea.

The image above shows a LIDAR image of land areas, a marina, and a dredged navigation channel.

Point Clouds

LIDAR scanners collect datasets in the form of point clouds, which are simply datasets of millions of geospatial referenced, data points which represent the point in space where the laser beam reflects from the surface and sends a “return” back to the scanner’s receiver circuitry.

These datasets are extremely large in terms of data quantity, and require up to date computing power for handling their storage and post processing. This raw data is usually not usable until it has been imported and converted for use in 3D modeling software programs.

Bathymetric LIDAR (dual frequencies for water and bed surfaces)

Bathymetric LIDAR is used for determining water depth by measuring the time delay between the transmission of a pulse and its return signal. Systems use laser pulses received at two frequencies: a lower frequency infrared pulse is reflected off the sea surface while a higher frequency green laser penetrates through the water column and reflects off the bottom surfaces. Analyses of these two distinct pulses are used to establish water depths and shoreline elevations.

Water Turbidity Problems

With proper water clarity, these systems can reach depths of 50 meters. However, turbidity is sometimes an issue by obscuring the laser, preventing it from reaching the bottom. However, recent advances in turbid water post-processing techniques are helping to remedy the situation.

Good choice for scanning complex shoreline areas
Bathymetric LIDAR is very useful in acquiring datasets in areas with complex and rugged shorelines, where surface vessels cannot operate efficiently or safely because of rocks, vegetation or breaking surfs.

US Virgin Islands (NOAA)

NOAA recently began a LIDAR-based survey of the shorelines of the U.S. Virgin Islands, where some of the charted areas were the last official US survey was in 1924. The high volume of vessel traffic transiting the Pillsbury Sound, between St. Thomas and St. John islands, makes this a critical area for NOAA hydrographic surveying.

Unlike more common topographic LIDAR that measures land elevation, a bathymetric LIDAR survey measures water depths and the shape and slope of the adjacent shoreline. NOAA uses bathymetric LIDAR data acquired by aircraft to augment its traditional vessel-borne hydrographic surveys.

While sonar surveys performed from boats provide greater resolution, an airplane flying a LIDAR system over a shallow coastal environment can cover a large area more quickly and safely.

The datasets gathered from these surveys will mostly be used to update NOAA’s nautical charts, however the data will also support a wide range of coastal management and marine habitat studies.

UAV (Drone-based) LIDAR

Recent advances in UAV technologies, and the greater affordability of both the UAV (unmanned aerial vehicle) and the LIDAR units, is making UAV-based LIDAR scanning a much more popular choice for scanning coastal areas and gathering bathymetric datasets.

This is creating a cottage industry for many adventurous surveying entrepreneurs, and opening new streams of revenue for hydrographic survey professionals.

Page 2: Marine Magnetometry

Localized Magnetic Field Variations

Local variations found within the Earth's magnetic field are most often caused by ferromagnetic objects or other magnetized objects which are located in the proximity of a given area. By measuring and recording these variations, it's possible to detect objects submerged beneath the water (and sediments). An accurate map of the object's position can be created by recording the sensor's position along with the magnetic variation.

Magnetometer

Marine magnetometry surveys are performed using a specially modified magnetometer, designed for use in marine survey operations. The magnetometer is installed in a water-tight towfish (image), which is dragged behind the vessel using a tow cable. These magnetometers come in a variety of designs, used for a variety of specialized applications.

Tow Cable

The magnetometer towfish shelled housing is connected to the data collection unit via a tow cable (image). The cabling plugs in to the towfish in the front, doubling as a tow cable and for data transmission to the electronics on the tow vessel.

Marine Magnetic Surveys

Magnetic surveys are very useful in the excavation and exploration of underwater archaeological sites. The apparatus used on the water slightly differs from that on land.

Marine magnetometers come in two types:

- Surface towed
- Near-bottom

Both types are towed at a sufficient distance from the ship to allow them to collect data without the data output being affected by the ship's magnetic properties.

Surface towed magnetometers allow for a wider range of detection at the expense of precise accuracy that is possible using near-bottom magnetometers.

Fluxgate Magnetometer

The most common type of magnetometer used in marine surveying applications is the "fluxgate magnetometer."

These types of magnetometers utilize two ferromagnetic cores each wound with a primary coil and an outer secondary coil attached to an ammeter. When an AC current passes through the primary coils, it creates opposing magnetic fields that vary in intensity based on the outside magnetic fields.

By floating them parallel to the seafloor, they can measure the changes in magnetic fields over the seabed.

Proton precession magnetometer

Another common type is the newer proton precession magnetometer. This utilizes a container full of hydrogen rich liquids (commonly kerosene or methanol) that, when agitated by a direct current or Radio Frequency (RF), cause the electrons to become energized, transferring the energy to the protons due to the "Overhauser Effect" basically turning them into dipole magnets.

When the stimulus is removed, the protons "precess" at a rate that can be interpreted to determine the magnetic forces of the area.

Applications

Magnetometers have a very diverse range of applications, including locating objects, such as:

- sunken vessels
- hazards for tunnel boring machines
- archaeological
- unexploded ordnance location (UXO)
- toxic waste drums
- as well as a wide range of mineral deposits and geological structures

Typical applications of marine magnetometry surveying are:

- Archaeologic studies
- Engineering studies
- Geologic studies
- Mineral exploration
- Search and recovery

Page 3: DC Marine Resistivity Imaging

Electrical Resistivity Imaging (ERI)

Electrical resistivity tomography (ERT) or electrical resistivity imaging (ERI) is a geophysical technique used for imaging sub-surface structures from electrical resistivity measurements made at the surface, or by electrodes in one or more boreholes.

If the electrodes are suspended in the boreholes, deeper sections can be investigated. It is closely related to the medical imaging technique electrical impedance tomography (EIT), and is mathematically the same inverse problem.

Induced polarization (IP)

A related geophysical method called "induced polarization" measures the transient response. The technique evolved from techniques of electrical prospecting that predate digital computers, where layers or anomalies were sought rather than images.

Self-potential (SP)

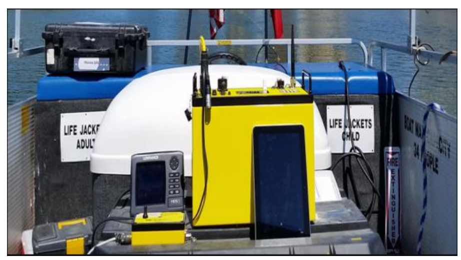
Self-Potential (SP) geophysical surveys measure the potential difference between any two points on the ground produced by the small, naturally produced currents that occur beneath the Earth's surface.

The SP method is passive, and non-intrusive; not requiring the application of an electric current. The self-potential method is traditionally used as a mineral exploration tool and for downhole logging in the oil industry, but recently it has been adapted for use in hydrogeological (groundwater) applications, by the use of more sensitive equipment and the careful application of data correction processes.

This technology is not suitable for use in most hydrographic applications.

Marine ERI

The marine-based ERI unit works in a similar fashion to the land-based model, with the electrode being towed behind a survey vessel instead of being dropped into boreholes.



Compared to land system, the Marine ERI is able to collect extraordinarily large amounts of data in an average day.

To use the marine module, you simply connect the accessories and then tow the sensor cable behind the boat at 2 to 4 miles/h. The module gathers continuous 2D scans. In an eight hour day, it is not uncommon to gather over 25 linear miles of data.

Marine DC electrical resistivity imaging (ERI) allows for the collection of streaming marine data using a towed cable rig. With marine ERI, hydrographic surveys can be performed with continuously recorded electrical resistivity imaging data. The recorded data contains positional

attributes from a GPS receiver, along with the depth profile measured with a 200 KHz echo sounder.

By towing an electrode array behind a ship and continuously recording data with the ERI unit, the marine resistivity set-up can record many times the line-distance of a traditional land-based ERI system.

Applications for Marine ERI

These include:

- characterizing sediment type (sand vs. clay) or identifying hard rock
- identifying zones of submarine groundwater discharge
- mapping geologic structures
- Determining sub-bottom geology for dredging purposes
- Monitoring leakage in a dam
- Mapping fresh and saltwater interfaces near shorelines or offshore
- Characterizing the sub bottom of estuaries
- Measuring water column salinity variations
- Mineral exploration (usually placer deposits)
- Locating freshwater springs at sea (submarine groundwater discharge)

Page 4: Radar Altimetry; Satellite-based radar

Radar Altimetry

A radar altimetry system is typically mounted on aircraft or satellite, and measures the altitude above the terrain which is presently beneath the altimetry unit by timing how long it takes for a beam of radio waves to reflect from the ground and return to the plane or satellite.

This type of altimeter provides the distance between the antenna and the ground directly below it, in contrast to a barometric altimeter which provides the distance above a defined datum, which is usually mean sea level.

Pulse-Limited Altimetry

With this type, the radar altimeter measures the return power of the radar pulse that's reflected off the land or ocean surface. The time differential for the reflected radar pulse is interpreted in order to estimate the distance between the radar altimeter and the reflecting surface. Surface irregularities can also be estimated. The expected return pulse can be derived from a few basic mathematical considerations.

Frequency modulated continuous-wave (FMCW) radar

With this system, the greater the frequency shift the further the distance traveled. This method can achieve better accuracy than the pulsed radar system using the same outlay. And radar altimeters that utilize frequency modulation (FM) are the industry standard.

As of 2010, all commercial radar altimeters use linear frequency modulation - continuous wave (LFM-CW or FM-CW). About 25,000 aircraft in the US have at least one radio altimeter unit onboard.

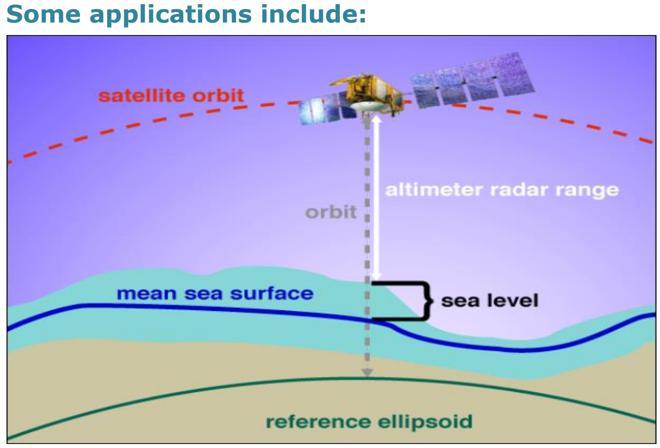
This includes all commercial transport and all business aircraft licensed to fly for hire, which are required to have at least two separate radio altimeters onboard each aircraft.

Delay Doppler (or SAR) Altimetry

The primary difference between Delay Doppler (or Synthetic Aperture Radar) and pulse-limited altimetry is that Delay Doppler altimetry looks at a smaller section of the pulse-limited radar footprint, but emits far more pulse signals to give the effect of covering the same footprint as pulse-limited but with better resolution.

Hydrographic applications for radar altimetry

Some applications include:



- For conducting static bathymetric surveys and current field observations analyzing the "Local Gravity Wave Dispersion*."
- For conducting dynamic profiling of sea currents by the "Radar Doppler Current Profiler" method.

***Water Wave Dispersion**

In fluid dynamics, dispersion of water waves generally refers to frequency dispersion, which means that waves of different wavelengths travel at varied phase speeds. Water waves, in this context, are waves propagating on the water surface, with gravity and surface tension as the restorative forces. As a result, water with a free surface is usually considered a dispersive medium.

For a given water depth

Surface gravity waves (i.e. waves which occur where the air and water meet) and gravity (as the only force restoring the surface to flatness), propagate faster with increasing wavelength.

For a given (fixed) wavelength

Gravity waves in deeper water have a larger phase speed than in shallower water.

In contrast with the behavior of gravity waves, capillary waves (i.e. only forced by surface tension) propagate faster for shorter wavelengths. Besides frequency dispersion, water waves also exhibit amplitude dispersion. This is a nonlinear effect, by which waves of larger amplitude have a different phase speed from small-amplitude waves.

Acoustic Doppler current profiler (ADCP)

An acoustic Doppler current profiler (ADCP) is a hydro acoustic current meter similar to sonar, attempting to measure water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column. The term ADCP is a generic term for all acoustic current profilers although the abbreviation originates from an instrument series introduced by RD Instruments in the 1980s.

The working frequencies range of ADCPs range from 38 KHz to several MHz.

Measuring Bathymetry

RA satellites can be useful in measuring bathymetry in the oceans. Satellite radar maps out the deep-sea topography by detecting the subtle variations in sea level caused by the gravitational pull of undersea mountains, ridges, and other land masses.

On average, sea level is higher over mountains and ridges than over abyssal plains and trenches.

Other uses of radar altimetry:

- Navigation
- Prediction of seafloor depth
- Planning shipboard surveys
- Identifying plate tectonics
- Underwater volcanoes
- Petroleum and gas exploration
- Identifying lithospheric structure

Page 5: Ground Penetrating Radar (GPR)

GPR

(GPR) Ground penetrating radar or georadar is a geophysics seismic method based on the use of focused radar energy which penetrates the ground to image subsurface conditions.

Recent advances in technology have led to more compact and better quality imaging systems which can be operated by a single technician, for performing a detailed examination of the subsurface. This system is used in shallow water in addition to dry ground.

Fresh water applications only (no salt water) Ground Penetrating Radar (GPR) can be used in fresh water lakes and river; however it cannot be used in salt water or brackish water due to the increased conductivity values of these water bodies.

Applications of GPR

GPR is used in freshwater environments to determine the bathymetry, and for profiling sub-bottom sedimentary stratigraphy and stratum interfaces.

It is also useful in identifying natural and man-made objects including cables, pipes, boats, outboards, logs and other artifacts buried deep in the sediment. It can be used in frozen regions to measure ice and permafrost thickness or to determine the structural aspects of ice and snow.

GPR is considered to be the most effective method, on land and for water bodies (rivers & lakes only), to obtain information of buried objects, buried pipelines, rails, and more.

This method has the advantage of being instantaneous in imaging the subsurface, allowing the technician to actually view the subsurface conditions while performing the data acquisition. The data is later post-processed for establishing the depth, diameter and other properties of detected pipes.

GPR is able to detect both metallic and non-metallic objects, and even objects very close to one another. It is effectively used for regions where the sea bottom has vegetation making it unsuitable for an ordinary depth sounder.

It can detect the presence of boulders, rocks or other objects lying on the sea floor or buried beneath the soil. The technique also detects geologic contacts and other features having a dielectric contrast with surroundings.

Principle of GPR

The operational principle of GPR is based on the propagation of electromagnetic wave impulses of very high frequency (40 to 1000 MHz) that are reflected by anomalies in the subsurface (such as joints, irregularities, and interfaces etc.), at varying depths and then recorded by the antenna. The system records the amplitude of the reflected signal and the two-way time it takes to complete the cycle in order to calculate the depth of the anomaly.

Page 6: Locating of UXO using GPR

Locating of UXO

The locating of (UXO) unexploded ordnances is also a valuable and life-saving application of marine GPR. Many UXO have wound up in the muck and sediment in wetlands throughout the world; even in the US.

GPR is useful in locating these ordnances which wind up submerged in freshwater.
Lakes, rivers, and wetlands are common on many military bases, especially within artillery and bombing ranges, some of which have been mandated to close and convert to public use.

Many of these ranges have been in use since the 1930s, but environmental mapping of stray ordnance has been implemented on some bases only within the last 20 years.

Of particular concern are dangers associated with shallow lakes because unexploded ordnance (UXO) are then close to waders, fishermen, motors, and paddles. Lakes and ponds may dry up and leave buried UXO dangerously close to the surface.

GPR vs. SONAR

GPR is a competing method against SONAR for locating submerged or buried UXO. As does SONAR, GPR can delineate sub bottom strata and detect localized objects within it, to resolution of a decimeter or better.

Unlike SONAR, GPR is able to operate from either an ice or a water platform, can propagate within a heavy suspended load, is not affected by vegetation or gaseous sediments, is not subject to masking reverberation in shallow water (as SONAR is), and is a more affordable option.

The image above shows UXO's on display at the Laos visitors center in Luang Prabang, Laos.

Chapter 5: Additional Topics

Page 1: Types and Causes of Tidal Cycles

Continental Interference

If the Earth were a perfectly shaped sphere with no large continental land masses, all regions of the globe would experience two equally proportioned high and low tidal cycles each lunar day. However, the large continents block the westward passage of the tidal bulges as the Earth rotates.

Without being able to move uninhibited around the globe, these tides establish complex patterns within each ocean basin that often differ greatly from tidal patterns of adjacent ocean basins or other regions within the same ocean basin.

Three types of Tidal Patterns

Three basic tidal patterns occur along the Earth's major shorelines:

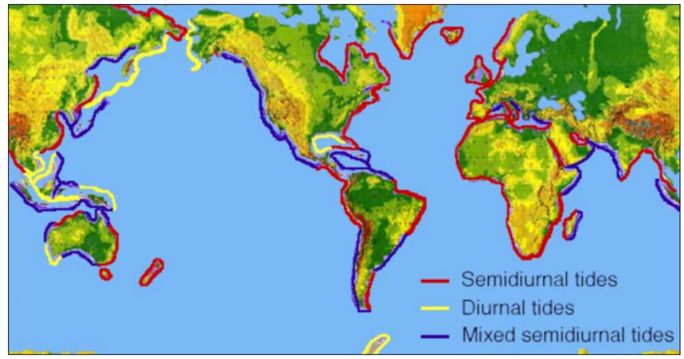
- Diurnal
- Semidiurnal
- Mixed Semidiurnal

Generally, most regions have two high tides and two low tides per day. When the two highs and the two lows are about the same height, the pattern is called a semi-daily or "semidiurnal" tide.

If the high and low tides differ in height, the pattern is known as a "mixed semidiurnal" tide. When an area has only one high and one low tide per day, this tidal pattern is known as a "diurnal" tide.

The US West Coast tends to have mixed semidiurnal tides, whereas a semidiurnal pattern is more typical of the East Coast, while the Gulf of Mexico is diurnal.

The following image shows a map which illustrates the geographic distribution of different tidal cycles. (Coastal areas with diurnal tides are yellow, areas with semidiurnal tides are red and regions with mixed semidiurnal tides are outlined in blue.)



High water and Low Water

The highest level reached by the water surface in one complete oscillation is known as high water, while the low water refers to the lowest level reached by the water surface in one oscillation.

Height of Tide

The height of tide is the vertical distance from a specified datum (in most cases the chart datum) to the level of the water surface at any time. The height of tide is usually a positive value, while negative values may still occur when the adopted datum is not low enough to take into account extreme low waters.

It is also possible to refer the tide to the mean sea level that is in relation to the average height of the surface of the sea. The height of the tide obtained thereby will be either negative, as in the case of low waters, or positive, as with high waters.

Range of Tide

The range or elevational difference of the tide, between consecutive high and low (or low and high) waters at one place, is variable.

Spring and neap tides

Spring tides and neap tides refer to the cases when the value of the range of tide is maximum and minimum respectively, which happens at time periods of roughly 14 days.

While a spring tide occurs around every new and full moon, a neap tide will occur around any of the two situations of quadrature, (which is the position of the moon when it is 90° from the sun as viewed from the earth.)

Page 2: Tidal Datums (Sounding and Chart)

Tidal phenomenon varies in different regions of the world, thus no single formula will satisfy all tidal regimes.

Concept of a Tidal Datum

A tidal datum can be understood to be the reference plane or surface to which the height of the predicted tide is referenced.

Two concepts derived from this may be:

- ***Sounding datum*** - the plane to which soundings are reduced in the course of a hydrographic survey.
- ***Chart datum (CD)*** - the plane of reference to which all charted depths and drying heights are related.

Sounding Datum

All depths indicated on nautical charts are reckoned from a selected level of the water called the sounding datum (which is sometimes referred to as the reference plane). For most NOAA charts of the US in coastal areas, the sounding datum is Mean Lower Low Water (MLLW).

Due to technical considerations, the chart datum is not always the same as the sounding datum; with the datum selected, generally being an arbitrary level.

Chart Datum

A chart datum is the level of water that charted depths, which are displayed on a nautical chart, are measured from. A chart datum is generally a tidal datum; meaning a datum derived from some phase of the tide. Common chart datums are lowest astronomical tide and mean lower low water.

Three considerations need to be taken into account when selecting a datum:

- Should be low enough under normal weather conditions, to have minimally the depth shown on the chart.
- Should not be so low as to give an unduly pessimistic idea of the least depth of water likely to be found.
- Should comply with the data of neighboring surveys.

Sounding and chart datums are low water datums, which refer to the level of the water surface at low tide. Additionally, there are datums based on high water levels, but they are not used as a reference level for depths in hydrographic surveys and nautical charts.

Vertical Datums

These two different datums may be included in the broader category of vertical datum, which comprises a plane or surface used as a reference to measure vertical distances (such as depths, drying features, heights on shore, etc.). Any tidal datum is thus a vertical datum.

Tidal levels, either high water or low water datums, have several definitions depending upon the information used to compute them; meaning that they vary according to the parameters that were considered in their calculation.

The existence of different definitions means that, when referring to high water or low water, attention must be drawn to the tidal reference being used.

Lowest astronomical tide

Many national charting agencies, including the United Kingdom Hydrographic Office and the Australian Hydrographic Service, use the Lowest Astronomical Tide (LAT) - the height of the water at the lowest possible theoretical tide - to define chart datums. LAT is the lowest levels which can be predicted to occur under average meteorological conditions.

One advantage of using LAT is that all predicted tidal heights must then be positive (or zero) avoiding possible ambiguity and the need to explicitly state sign.

Calculation of the LAT only allows for gravitational effects so lower tides may occur in practice due to other factors (e.g. meteorological effects such as high pressure systems).

Mean lower low water

NOAA uses mean lower low water (MLLW), which is the average height of the lowest tide recorded at a tide station each day during the recording period (the National Tidal Datum Epoch - a 19 year period). MLLW is only a mean, so some tidal levels may be negative relative to MLLW, such as mean low water spring.

Mean low water spring

This is the average of the levels of each pair of successive low waters during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest (Spring Range).

Charts and tables

Charted depths and drying heights on nautical charts are given relative to chart datum. Some height values on charts, such as vertical clearances under bridges or overhead wires, may be referenced to a different vertical datum, such as Mean High Water Springs or Highest Astronomical Tide.

Tide tables give the height of the tide above a chart datum making it feasible to calculate the depth of water at a given point and at a given time by adding the charted depth to the height of the tide.

One may calculate whether an area that dries is under water by subtracting the drying height from the given height calculated from the Tide table. Using charts and tables not based on the same datum can result in incorrect calculation of water depths, so care should be taken to always confirm their compatibility.

Chart Datum and GNSS

In recent years national hydrographic agencies have spearheaded developments to establish Chart Datum with respect to the GRS 80 reference ellipsoid, thus enabling direct compatibility with GNSS positioning.

Page 3: U.S. Maritime Limits & Boundaries

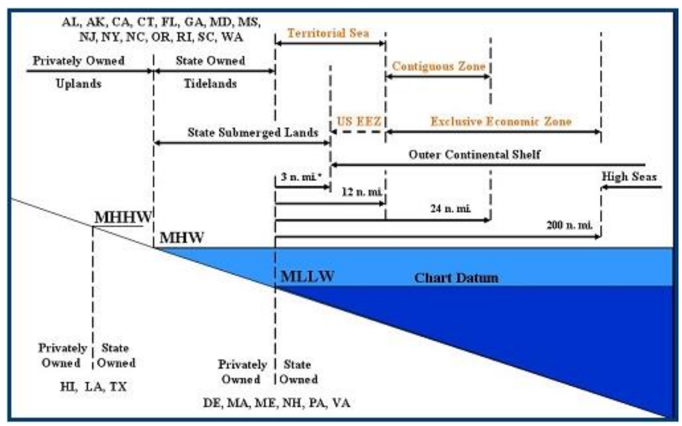
Maritime limits and boundaries

Maritime limits and boundaries for the US are measured from the official US baseline, (which is recognized as the low-water line along the coast as marked on the NOAA nautical charts in accordance with the articles of the Law of the Sea.)

The Office of Coast Survey depicts on its nautical charts the territorial sea (12 nautical miles), contiguous zone (24 nautical miles), and exclusive economic zone (200 nautical miles, plus maritime boundaries with adjacent/opposite countries).

General Information about U.S. Maritime Limits and Boundaries

NOAA is responsible for depicting on its nautical charts the limits of the 12 nautical mile territorial sea, 24 nautical mile contiguous zone, and 200 nautical miles Exclusive Economic Zone (EEZ). These zones are highlighted in orange in the image below.



Territorial Sea

The territorial sea is a maritime zone over which the US exercises sovereignty. Sovereignty extends to the airspace above and to the seabed below the territorial sea. The US territorial sea extends 12 nautical miles from the baseline.

Contiguous Zone

The contiguous zone of the US is a zone contiguous to the territorial sea. In this zone, the US may exercise the control required to prevent and punish any infringement upon its customs, fiscal, immigration, cultural heritage, or sanitary laws and regulations within its territory or territorial sea. The US contiguous zone is measured out to 24 nautical miles from the baseline.

Exclusive Economic Zone (EEZ)

The exclusive economic zone (EEZ) of the US extends 200 nautical miles from the territorial sea baseline and is adjacent to the 12 nm territorial sea of the U.S., overlapping the 12-24nm contiguous zone.

Within the EEZ, the US has sovereign rights for the purposes of:
The exploration, exploitation, conservation and management of natural resources, whether living and nonliving, of the seabed and subsoil and the superjacent waters
And with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds jurisdiction (as provided for in international and domestic laws with regard to the establishment and use of artificial islands, installations, and structures, marine scientific research, and the protection and preservation of the marine environment, and other rights and duties provided for under international and domestic laws)

Certain U.S. fishery laws use the term “exclusive economic zone” (“EEZ”). While the outer limit stated in these laws is the same as the EEZ on NOAA charts, the inner limit generally extends landward to the seaward boundary of the coastal states of the US For the seaward limit of the state’s jurisdiction under the Submerged Lands Act.

Maritime Boundaries with adjacent and opposite countries

Maritime boundaries with adjacent and opposite countries are established through agreement and treaties with these neighboring nations. More information concerning these treaties can be found online at the Department of State website on “US Maritime Boundaries: Agreements and Treaties.”

Page 4: (AUV) Use of Autonomous Underwater Vehicles

Autonomous Underwater Vehicles (AUV)

Autonomous Underwater Vehicles (AUV), also known as unmanned underwater vehicles, can be used to perform underwater survey tasks such as detecting and mapping submerged wrecks, rocks, and obstructions that pose a hazard to commercial navigation and recreational vessel travel.

The AUV (see image) conducts its survey tasks without the need for operator participation. When a mission is completed, the AUV will return to a pre-programmed location and the data collected can be downloaded and processed in the same way as data collected from shipboard systems.

> **AUV Components**
> *NOAA’s hydrographic survey AUVs are typically equipped with:*
> - Side scan sonar
> - Conductivity-Temperature-Depth (CTD) sensors
> - GPS-aided Inertial Navigation Systems (INS)
> - Acoustic Doppler Current Profiler (ADCP)

AUVs can be equipped with a wide variety of oceanographic sensors or sonar systems. Currently, NOAA’s Coast Survey Development Lab is evaluating the use of Autonomous Underwater Vehicles (AUV) as tools for hydrographic surveying, to support their nautical charting missions.

The use of AUVs, in collaboration with NOAA’s manned survey fleet, could greatly increase survey efficiency.

Additionally, AUVs could be used for marine incident response and port security surveys due to their small size and flexible deployment options.

AUV vs ROV

The primary difference between an AUV and a Remotely Operated Vehicle (ROV) is that the AUVs operate on their own, independently of the ship and have no connecting cables.

Page 5: Remotely Operated Vehicles (ROV)

Remotely Operated Vehicles (ROV)

A Remotely Operated Vehicle (ROV) is an unoccupied underwater robot which is connected to a topside control unit by a series of tethering and transmission cables.

The connecting cables transmit the command and control signals between the underwater vehicle and the ROV technician, allowing remote navigation of the vehicle.

Components of an ROV

A remotely operated underwater vehicle has three main components:

- ***Topside control unit*** – which includes: hand box controller, laptop computer, video display
- ***Remote Vehicle*** – which includes propulsion and steering, housing, and attachments
- ***Cabling and Tether management system*** – for data and signal transmission, and tethering to prevent loss of the unit

A typical hydrographic ROV configuration might include the following attachments:

- ***Video camera*** – for locate and retrieve, exploration, etc.
- ***lighting*** – for illumination, to navigation and retrieval purposes
- sonar systems – for sounding purposes, and hydrographic surveying tasks
- an articulating arm – for retrieval of small items, to cut lines, or to attach lifting hooks to for retrieving larger objects

Applications of ROV Units

Typical hydrographic uses for the ROV include locate and retrieve operations for small objects, object identification (such as submerged navigation

hazards), vessel hull inspections, and least depth determination. This system is not intended as a replacement for hydrographic diver investigations, but could serve as a substitute when the safety of the diver is in question, or when divers are not available.

The CSDL, mentioned below, is evaluating the use of a commercially available ROV.

The ROV is an inspection class vehicle equipped with a forward-looking high-resolution color zoom video camera. There are two fixed-focus low light cameras that can be mounted on the ROV sides, facing aft of the vehicle, or on the bottom of the vehicle, facing down.

A high resolution imaging sonar is also available, increasing the ROV's 'visual' range and functionality in varying conditions.

Up to 300 meters of neutrally buoyant tether are available for operations in depths up to 150 meters and an articulating arm is mounted on the front of the ROV. Sonar records as well as digital video imagery are products from ROV dives.

Coast Survey Development Lab (CSDL)

NOAA's Coast Survey Development Laboratory explores, develops, and transitions emerging technologies and techniques of charting, hydrographic, and oceanographic systems used by the Coast Survey and NOAA to support safe and efficient marine navigation and a healthy and sustainable coastal environment.

From looking at new methods of obtaining accurate depth data using autonomous underwater vehicles and interferometric side scan sonars to the development of models that provide forecast guidance to the Nation's shipping community and others, a variety of interesting projects and experimental products are available here for review.

Page 6: NOAA's Unmanned Aircraft Systems Program (UAS)

Unmanned Aircraft Systems (UAS)

Unmanned Aircraft Systems (UAS) can potentially revolutionize the ability for NOAA to monitor and understand our land and sea environments. There are gaps in key information, between the instrumentation on Earth's surface and on satellites, which UAS can fill.

Operated by remote pilots and ranging in wingspan from less than six feet to more than 115 feet, UAS can also collect data from dangerous or remote areas, such as the poles, oceans, wildlands, volcanic islands, and wildfires.

Better data and observations improve understanding and forecasts, save lives, property, and resources, advancing NOAA's mission goals.

NOAA has been involved with the testing and development of UAS for several years. Collaboration with NASA and industry partners in 2005-2007 resulted in a series of tests using both large and small UAS for various applications. Since those beginnings, the NOAA UAS Program was formally established and has been expanding UAS research, development and transitions to operations and commercialization.

UAS Components

The typical UAS consists of an unmanned aerial vehicle, a launch system, a recovery system, a video camera payload carried aboard the UAV, and a ground control system.

The vehicle will usually have a propulsion system in the rear section, a turret in the nose section (to mount and rotate the survey instrumentation), and the avionics (aviation electronics) within the forward fuselage section.

Page 7: Fisheries Acoustics

Not all hydrographic surveying with echo sounding, consists of bathymetric measurements, depth measurements, and such. The detection and measuring of marine life is another form of survey which can be accomplished with sonar devices.

Fisheries Acoustics

Fisheries acoustics includes a range of research and practical application topics using acoustical devices as sensors in aquatic environments. Acoustical techniques can be applied to sensing aquatic animals, zooplankton, and characteristics of physical or biological habitats.

Biomass Estimation

Biomass estimation is a method of detecting and quantifying fish and other marine organisms using sonar technology. An acoustic transducer emits a brief, focused pulse of sound into the water. If the sound encounters objects that are of different density than the surrounding medium, such as fish, they reflect some sound back toward the source. These echoes provide information on fish size, location, and abundance.

High Quality "fishfinders"

The basic components of the scientific echo sounder hardware function is to transmit the sound, receive, filter and amplify, record, and analyze the echoes.

While there are a number of manufacturers of commercially available fishfinder equipment, accurate quantitative analysis requires that measurements be made with calibrated echo sounder equipment, having high signal-to-noise ratios.

Sonars

The primary tool in fisheries acoustics is the scientific echo sounder. This instrument operates on the same principles as a recreational or commercial fishfinder or echo sounder, but is engineered for greater accuracy and precision, allowing quantitative biomass estimates to be made.

In an echo sounder, a transceiver generates a short pulse which is sent into the water by the transducer, an array of piezoelectric elements arranged to produce a focused beam of sound.

In order to be used for quantitative work, the echo sounder must be calibrated in the same configuration and environment in which it will be used; this is typically done by examining echoes from a metal sphere with known acoustic properties.

Early echo sounders only transmitted a single beam of sound. Because of the acoustic beam pattern, identical targets at different azimuth angles will return different echo levels.

If the beam pattern and angle to the target are known, this directivity can be compensated for.

Twin Beam Echo Sounder

The need to determine the angle to a target led to the development of the twin-beam echo sounder, which forms two acoustic beams, one inside the other. By comparing the phase difference of the same echo in the inner and outer beams, the angle off-axis can be estimated.

Split Beam Echo Sounders

In a further refinement of the above concept, a split-beam echo sounder divides the transducer face into four quadrants, allowing the location of targets in three separate dimensions.

Single-frequency, split-beam echo sounders are now the standard instrument of fisheries acoustics.

Multibeam Sonars

Multibeam sonars project a fan-shaped set of sound beams outward into the water and record echoes in each beam. These have been widely used in bathymetric surveys, but have only recently begun to find use in fisheries acoustics applications.

Their main advantage is the addition of a second dimension to the narrow water column profile given by an echo sounder. Multiple pings can thus be combined to give a three-dimensional picture of animal distributions.

Acoustic Cameras

Acoustic cameras are instruments that image a three-dimensional volume of water instantaneously. These typically use higher-frequency sound than traditional echo sounders.

This increases their resolution so that individual objects can be seen in detail, but means that their range is limited to tens of meters.

They can be very useful for studying fish behavior in enclosed and/or murky bodies of water, for instance monitoring the passage of anadromous fish at dams.

Target Strength (TS)

This is a measure of how well a fish, zooplankter, or other aquatic target scatters sound back towards the transducer; in general, the larger the marine life, the larger the target strength. Other factors, such as the presence or absence of a gas-filled swim bladder in fish, may have a much larger effect.

Target strength is of critical importance in fisheries acoustics, since it provides a link between acoustic backscatter and animal biomass.

TS can be derived theoretically for simple targets such as spheres and cylinders, but in practice, it is usually measured empirically or calculated with numerical models.

Bibliography

1) Much of this course is based on articles obtained from the National Oceanographic and Atmospheric Administration,
(NOAA), and the Office of Coast Survey
2) Some course material comes from Wikipedia and images from Creative Commons
3) Some materials are based on information gathered from Corp of Engineers publications
4) Based on materials from the USGS or US Geological Survey
5) Portions of the magnetometry page were based on an article by Geophysics GPR International
6) Hydrographical standards are gathered from the International Hydrographic Organization (IHO)
7) Marine ERI course materials were based in part on information gather from (AGI) Advanced Geosciences Inc.
8) Course materials on UXO, were based on articles from SERDP and ESTCP.