FACTS ABOUT

An Information Update from the IADC

UNDERWATER SURVEYS

WHAT IS SURVEYING?

Surveying is the science of accurately determining the area of any portion of the Earth's surface, be it on land or underwater. The general aim of surveying is to measure and fix a position in three dimensions. Underwater or hydrographic surveys are part of the data collection process used during dredging and maritime infrastructure works to establish the seafloor and subsea conditions and monitor dredging accuracies. Surveying is an essential element and a prerequisite in the planning and execution of nearly every form of construction project including maritime and dredging projects. Nowadays data can be stored on computers and shared, providing crucial information to dredging contractors and their clients.

WHY ARE SURVEYS NECESSARY FOR DREDGING?

Surveying is indispensable in the modern dredging industry. Surveys are used to collect data about navigable waters – including oceans, seas, lakes and rivers – in order to ensure navigational safety. Port authorities, for instance, are charged with guaranteeing safe and accurate navigational depths so surveying the port and access channels is crucial. Surveys are used to gather data for capital (new projects) as well as maintenance dredging where they help determine the total amount of soil which must be removed. Surveys are used to check if the design depth is reached over the entire area. Surveys are also used in the offshore industry from the initial design to follow-up inspections of the completed subsea gas or oilfield infrastructure. For instance, whilst trenching and backfilling operations for pipeline laying the trenches can be measured to ensure the proper profile has been made in which to lay the pipe. Afterwards the accuracy of backfilling with rock can be monitored.

WHAT IS A HYDROGRAPHIC SURVEY?

A hydrographic survey is a scientific process for describing and analysing the physical conditions, shoreline boundaries, tides, waves, currents, wind, submerged obstructions and related characteristics of a body of water. These measurements describe features which affect maritime navigation, marine construction, dredging, offshore oil exploration and drilling and related activities. During dredging, hydrographic surveys are used to verify dredging accuracies and to measure the production performance and efficiency of dredging equipment.

WHAT IS A BATHYMETRIC SURVEY?

Part of hydrographic surveying is bathymetry, which is a topographical survey of the seabed. Whilst land surveys are relatively static, bathymetric measurements are dynamic as the surveying vessel is moving through the water. Bathymetric surveys use acoustic sounding to measure water depth by bouncing a sound wave from a transducer (a transmitting and listening device) mounted on a ship to the seafloor and then back to a receiver. The depth of the seabed can then be calculated. The data derived from such bathymetric measurements are often compiled in a topographic map or chart that shows the underwater terrain or seafloor relief as contour lines. The accuracy of bathymetric data is dependent on the quality of the acoustic sounding and the acoustic wave velocity, the position and motion of the ship and the reference level and tide corrections.

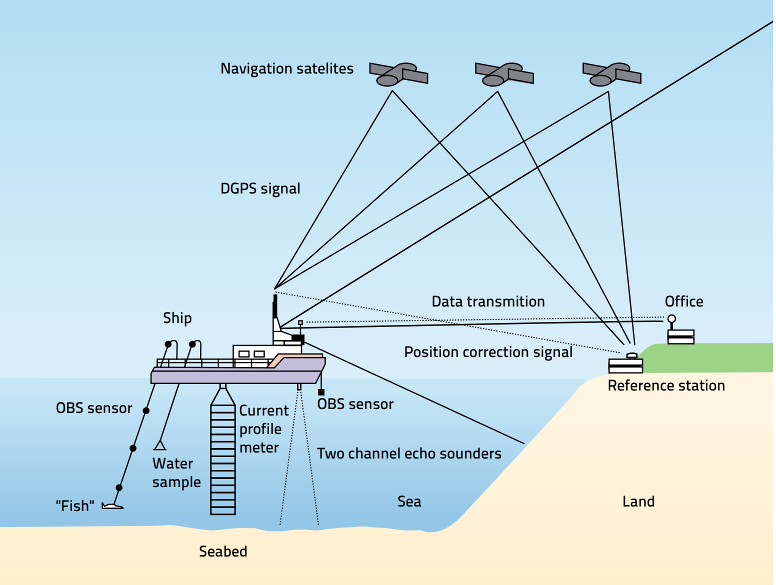
WHAT TOOLS ARE USED FOR SURVEYING?

Hydrographic or underwater surveying technologies for dredging activities include many techniques such as echo-sounding, in-situ density profilers and satellite positioning systems. Echo-sounding systems are the most usual technique used for surveying. They are used for maritime safety as well as for scientific or engineering bathymetric charts. Other information can then be extracted for specific applications.

WHAT IS ECHO-SOUNDING?

Echo-sounding is a type of sonar which transmits sound pulses into water. The time interval between emission and

Above: A fully equipped survey vessel with an overview of measurement equipment including a frame for an ADCP. Highly trained scientists are responsible for conducting surveys.



Some potential surveying methods used during dredging operations.

return of a pulse is recorded. This is used to determine the water depth. Hydro-acoustic echo-sounders are also used to study fish and underwater habitats. Hydro-acoustic assessments can use either mobile surveys from boats to evaluate fish biomass and spatial distributions or fixed-location techniques where stationary transducers monitor passing fish. Echo-sounding is carried out by single beam or multi-beam echo-sounders.

HOW DOES A SINGLE BEAM SYSTEM WORK?

A single beam system comprises a transmitter and a receiver which uses one sound pulse aimed directly below the survey vessel and thus measures one part of the bed. By sailing parallel survey lines, the area between the survey lines is measured and a bathymetrical map can be created. The system can be used both in shallow and deeper waters. The seabed is a good reflector of acoustic sounding, however, when muddy layers are encountered it may be less accurate. Much depends on the sound frequencies (kHz) that are used. When high-density seabed-covering data is required, a multi-beam echo-sounding system may be the appropriate choice.

HOW DOES A MULTI-BEAM SYSTEM WORK?

Multi-beam echo-sounding works on a system similar to a single beam but differs in that it uses a larger number of sound beams mounted in an arc. A good multi-beam system will have 100 or more transducers, whose output can be combined so as to enhance the sound transmitted towards or arriving from a particular direction. By measuring the sound travel time between the seafloor and the transducer and other parameters, including the angle between the area of the seafloor and the sender, one can calculate with good accuracy the seafloor's surface. Seismic reflection surveys emit signals that are able to penetrate the seafloor to sub-bottom sediment layers and are used for geological and geotechnical investigations, i.e., they can measure the thickness of sediment layers.

WHAT IS A SIDE SCAN SURVEY?

Side scan sonar is used to create an image of large areas of the seafloor. This is an efficient tool for mapping the seabed for a wide variety of purposes, including the creation of nautical charts and the detection and identification of underwater objects, such as debris, rocks, pipelines and so on. It is not a measuring system like echo-sounding.

WHAT IS AN ACOUSTIC DOPPLER CURRENT PROFILER?

An Acoustic Doppler Current Profiler (ADCP) is a sonar tool that records water current velocities over a range of depths. It may use two or more ceramic transducers, which are pointed so that the sound pulses they issue move through the water in various, but regulated directions. The echo of the sound is returned by scatterers in the water, and as a result of the Doppler Effect, the frequency of the sound shifts. ADCPs can be configured horizontally for side-looking in rivers and canals for long-term, continuous discharge measurements. They can be mounted on boats for instantaneous surveys of water currents and depths or placed on the seabed for long-term current and wave studies. ADCPs may be used to locate severe currents underwater that may affect dredging activities and they can give actual, up-to-date environmental data about the movement of dredged materials or the extent of turbulence. In addition, self-contained, battery-charged ADCPs can operate for years in rivers or remote bodies of water. After a length of time ADCPs are retrieved and the accumulated historical current data can be transferred from the ADCP memory to a computer which provides long-term water current profiles for planning dredging projects.

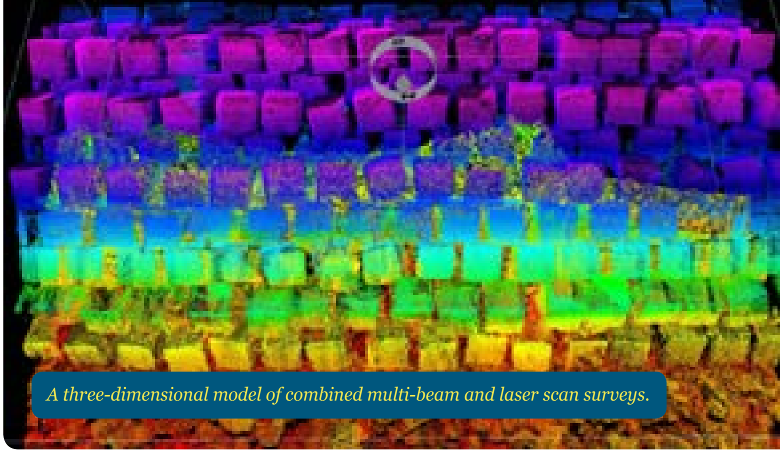
WHAT IS LIDAR?

LiDAR is a sensing technology that uses light pulses in the form of a laser to measure variable distances from the Earth, providing three-dimensional information about the surface characteristics and shape of Earth. This helps mapping professionals to study artificial as well as natural environments for numerous purposes. LiDAR (light detection and ranging, a play on the word radar) is used to survey dredging placement areas, assist with hydrographic surveys and collect data that will help analyse beach erosion. It has been used to characterise various benthic habitats in coral reef ecosystems. LiDAR survey data can help determine the current topography and dredge material capacity of placement areas.

WHAT KINDS OF VESSELS ARE USED FOR SURVEYING?

Often dedicated survey ships are being used. But survey equipment can be installed on inflatable craft, such as Zodiacs, small craft, autonomous underwater vehicles (AUVs), unmanned underwater vehicles (UUVs) or large ships. In other cases side-scan, single-beam and multi-beam surveying equipment is mounted on the dredging ship itself, especially on trailing suction hopper dredgers. When this equipment is mounted on the bow or bottom of the dredger cross-profiles of the seabed can be exhibited three-dimensionally on a computer as the vessel moves forward. The crew is thus able to anticipate and optimise dredging works and carry out bathymetric surveys as well. In areas where detailed bathymetry is required, an AUV can be deployed to make a high resolution map. Although traditionally conducted by vessels, surveys are increasingly

The visualisation of a multi-beam echo-sounding.



A three-dimensional model of combined multi-beam and laser scan surveys.

conducted with the aid of aircraft, satellites and drones with sophisticated electronic sensor systems.

WHAT ABOUT SATELLITE POSITIONING SYSTEMS?

Nowadays satellites are able to provide Global Positioning Systems (GPS) for all kinds of uses. The dredging industry as well makes extensive use of GPS, differential GPS (dGPS) and Real Time Kinematic (RTK) positioning. The use of satellite navigation techniques like dGPS and RTK has improved the accuracy of dredging to within centimetres. This increased precision offers an essential improvement when dredging for the offshore industry, e.g., laying pipelines, as well as during environmental dredging projects involving contaminated sediments.

HOW ARE DRONES USED FOR SURVEYS?

Another addition to the arsenal of surveying technology is the drone. Whilst earlier used for other purposes, this technology has recently been applied to surveying and remote sensing. Drones, also known as unmanned aircraft systems (UASs) or unmanned aerial vehicles (UAVs), have been developed with cost-effective drone technology and lightweight digital cameras which makes them viable for surveying.

HOW DOES SURVEYING SUPPORT DREDGING FOR SAND?

For extensive land reclamation projects, large quantities of sand are needed. Seabed surveys are necessary to determine the presence of sand, including the distance of sand borrow pits from the coastal stretch under consideration, the depth below sea level of the sand and the types and quantities of sand available. Before attempting to mine sand, the presence and position of the borrow areas must be located through bathymetric and seismic reflection surveys, grid positioning, gravity coring, vibrocoring and cone penetration tests and by using boreholes for sampling. The samples are then laboratory tested so that the characteristics of the sand, including average grain size, grain size distribution, mineralogical type and specific density, are determined.

HOW IS SURVEYING FOR ROCK WORKS DONE?

Surveying rock that has been placed underwater presents more challenges than surveying sandy seafloors or placing rock on dry land. Surveying rock on dry land is a relatively direct exercise. Surveying rock placement underwater means determining the level of the tops of the placed stone and the position of the reference plane. Acoustic beams unfortunately may not always hit the tops of the stone level, but rather go in between the rocks to the seafloor. This distorts the data and gives inaccurate measurements. Accuracy is also affected by the diameter of the stones used: the smaller the stones, the higher the accuracy. During a large operation, surveys are sometimes done on a spot-check basis. This saves time and money in the short run, but increases the risk of missing a bed area where rock placement is incorrect. The importance of using highly trained personnel and a quality surveying system cannot be underestimated.

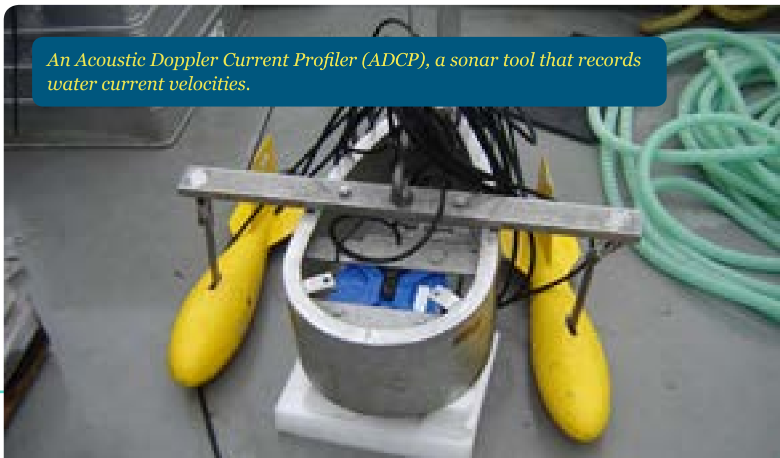
WHAT OTHER TOOLS ARE USED FOR SURVEYING?

Some harbours and access channels consist of loosely packed silt layers. Often ships with deep-draughts can still manoeuver through this so-called fluid mud. To ascertain this, the density level of the fluid mud must be determined, but this muddy layer is hard to measure with acoustic hydrographic survey tools. In these cases, surveying can be done with an in-situ density profiler to establish the 'navigable depth', that is, the physical level within the fluid mud layer which is still safe for deep-draughted vessels. Such an in-situ density profiler might be, for instance, a towfish with built-in transmission gauges and pressure sensors. The 'navigable depth' concept can reduce maintenance dredging resulting in cost-savings for port authorities without sacrificing safety.

HOW ACCURATE ARE SURVEYS?

The accuracy of a survey is essential to the proper execution of a project. Surveying accuracies are dependent on the quality of the sounding installation; the quality of the people operating the equipment; the nature of the bed surface being surveyed; the depth and nature of the waters; and the basic structure of

A multi-beam sonic projector on top with receiver module underneath.



An Acoustic Doppler Current Profiler (ADCP), a sonar tool that records water current velocities.

An unmanned aircraft: The aircraft is powered by electric propulsion and carries a calibrated camera. Flights and landings are fully automated.

the survey system. Surveying should be done with stringent requirements with respect to the vertical and horizontal accuracies of the profile to be done. For both the client and the contractor to avoid unnecessary risks and cost, these issues should be addressed early on in a project.

WHAT ARE THE IMPACTS OF SURVEY INACCURACIES?

Surveying inaccuracies can have negative consequences for a project, especially when operations involve rock placement where inaccuracies are more liable to take place. These inaccuracies can be categorised into random errors or systematic errors. Random errors can be caused by unexpected noise levels, which may cause an under- or overestimation of the level of the stones or the thickness of the layers. A systematic survey error means that the measurements deviate from the actual mean values. These systematic errors can result from poor or incomplete depth surveys. A layer that is too thick or not thick enough can lead to a failure of the bed-protective operation in the placement area. It also increases the chances that a ship will run aground. When an error occurs, serious questions arise: What is considered a feasible margin of error? And who is financially responsible to correct the errors?

HOW CAN SURVEYING LIMIT CONFLICTS?

Before a dredging work commences the client and contractor need to establish ground rules of expectations and clear specifications for the job. In the case of most dredging operations only a few, small systematic and random errors are likely to occur. These can be stipulated from the start. When monitoring a rock placement area, however, errors can occur of such magnitude that clear agreements are difficult to reach. This means that when writing specifications for stone placement works all possible survey errors and uncertainties must be considered and anticipated. The words ‘survey accuracy’ must be unambiguously defined to ensure that communications between the client and contractor are explicit and that risks are evenly divided between the two if requirements are not met. Clarity in the contract regarding surveying can avoid conflicts down the road.

ARE SURVEYS COST-EFFECTIVE?

Surveys for dredging projects are conducted using a wide range of tools. These surveys create a base line before a project starts that are stored. They are followed by continuous surveys throughout the lifetime of a project. Although investing in extensive survey data collection may appear costly, in the long term good surveys are a valuable investment: Margins of error decrease, dredging accuracies increase and this directly lowers overall costs. In general, whatever the type of dredging operation, surveying can be used to assemble data to make detailed progress reports and calculations thus ensuring a more successful dredging result.

FOR FURTHER READING AND INFORMATION

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Facts About is presented by the International Association of Dredging Companies whose members offer the highest quality and professionalism in dredging and maritime construction. The information presented here is part of an on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction.

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