A SunCam online continuing education course

Dredging and the Environment

Continuing Education Course

Part 1: Dredging 101

Course Summary:

This is a multi-part course that examines dredging as it relates to various types of environmental projects. This is Part One, essentially Dredging 101, which will give the reader a basic understanding of the fundamentals of dredging. Points that will be covered are:

1. The basic methods of dredging (Mechanical and Hydraulic).
2. The types of commonly available dredging equipment.
3. The basic dredging operation and differences in the methods.
4. The character of - and working with common dredged materials.
5. Selection of the dredge method for common types of projects.
6. The important advantages and disadvantages of each method.
7. The basics of underwater grade control (bathymetric or hydrographic survey).

This course is recommended as an introduction to “Dredging and the Environment Parts 2 and 3”, which focus on Dredging as it relates to Environmental Restoration Projects. Dredging applications that will be examined in Part 2 will be remediation and contaminated sediment removal, while Part 3 will cover beach and dune nourishment, and wetland habitat restoration.

A special note on dredging projects in general: All dredging projects require some level of regulatory oversight permitting – involving Federal, State and other authorities. However, dredge permitting is discussed only briefly in these courses, because dredge permitting in and of itself is very complex, and would expand these lessons far beyond the scope of a continuing education program. As such this document is intended to focus on introducing the subject of the actual dredging processes themselves, and will only discuss permitting matters as the need arises.

Use of this course material for design purposes is strictly subject to the following limitations and disclaimers set forth herein, which are as follows:

This course is intended only as a study guide of design considerations and is limited to the specific types of projects discussed within this specific course. It is not intended nor is it possible within the confines of such a course to cover all aspects of dredging design or permitting. It is not intended that the materials included herein be used for design of facilities that exceed the size or exposure limitations as demonstrated by the examples. Nor is it intended that an engineer that is inexperienced in maritime design should study this course and immediately undertake design or permitting of a dredging project without some oversight or guidance from someone more experienced in this field. This is especially important for design of projects that could potentially adversely affect the environment. It is important to know that there are an abundance of regulations that cover dredging projects and how it is to be conducted - such as to minimize its impact on the environment. Failure to properly follow regulatory procedures can result in severe penalties or other liabilities. This course is intended to build the engineer's understanding of maritime design so that he or she can work with other engineers who are more experienced in this area and to allow them to contribute meaningfully to a project. The author has no control or review authority over the subsequent use of this course material, and thus the author accepts no liability for secondary damages that may result from its inappropriate use. In addition this document does not discuss environmental or regulatory permitting in significant detail, which is a key component of maritime projects; permitting issues are best taken up with permitting specialists early in the conceptual phases of a project, as regulatory issues can dramatically affect the final design.

Portions of this document refer to the US Army Corps of Engineers Shore Protection Manual and Coastal Engineering Manual; and the US Army Corps of Engineers Engineering Manual on Hydrographic Surveying – EM-1110-2-1003 we wish to formally thank the COE and acknowledge the contributions and research done by the US Army Corps of Engineers as well as the US Army Waterways Experimental Station, & Coastal Engineering Research Center, Vicksburg, Mississippi for their work in producing these manuals. We also wish to thank the producers of Hypack Software for their pioneering efforts and contributions to the advancement of Dredging and Hydrographic Software solutions.

Part 1: Dredging 101:

Overview:

Dredging for the purposes of this course will be defined as the removal any type of soil from the land that underlies any almost body of water. With that said however, this course will focus primarily on dredging projects that - because of site specific conditions must be performed from floating equipment. Conversely, underwater excavation from land (such as the use of shore based clamshell cranes, backhoes or draglines) – while technically considered as "dredging" – typically does not bear the challenges associated with projects that require the use of floating equipment. As such land based projects will only be discussed briefly herein. While the process of dredging has a long and varied history, in the present day the most common types of dredging projects are:

1. Navigation Dredging: Dredging to deepen a waterway to allow the passage of floating vessels. This type of dredging can be for the purpose of creating or deepening an existing channel, also maintaining an existing channel that has filled in by the natural sedimentation process.
2. Beach Nourishment: This is the type of dredging that takes sand and/or gravel from an underwater source, and pumps it to shore where it is deposited on beaches to replace eroded materials or replenish/ re-establish damaged dunes.
3. Construction Dredging: Dredging related to some form of construction project, such as highway tunnels that go under waterways, pipeline trenches, and bridge approaches.
4. Environmental Dredging (Habitat Restoration): Dredging that takes place to restore some form of lost marine habitat, such as replacement of eroded intertidal wetlands, or restoring original bottom depths to water bodies that have filled in from erosion. This can also include removal of accrued muddy sediments where underlying sandy bottom materials are preferred for restoration of marine habitat.
5. Environmental Dredging (Remediation): Dredging that takes place to remove contaminated sediment from a waterway, and follow-on

treatment and disposal. Levels and types of contamination can vary considerably, each requiring their own level of control, treatment and worker protection.

6. Capping: The use of dredging equipment to place sand and/or gravel in a body of water, either to cap contaminated material that is to be isolated, or to prevent underlying or nearby contaminants from leaching into the waterway.

There are other possible applications for dredging technology that are derivations of the above. This course (Parts 1 to 3) will focus on dredging as it relates to the Environment as generally described in items 2, 4, 5 and 6 above. For other types of dredging applications the reader may contact the "Western Dredging Association", or for general information contact "World Dredging" magazine or "International Dredging Review".

Precautionary Note: Almost all dredging projects will fall under Federal regulatory control at some level. There are two very important Federal regulations that apply to dredging in navigable waterways, and anyone undertaking a dredging project should have some understanding of them. These are the "Jones Act" and the "Rivers and Harbor Act"; violation of either of these acts (mostly the later) carries very severe penalties. Thus it is recommended that the designer review these documents with an expert in this area before taking on a dredging project in any navigable waterway.

Basic Types of Dredges:

There are fundamentally two methods of dredging; the first is termed "Mechanical Dredging", the second is termed "Hydraulic Dredging". Dredges in each category come in all shapes and sizes – depending on project needs. Figure 1, below is an example of a hydraulic dredge, the one shown is of the small, portable variety, which are quite common. Figures 1 and 2 show some of the basic components:

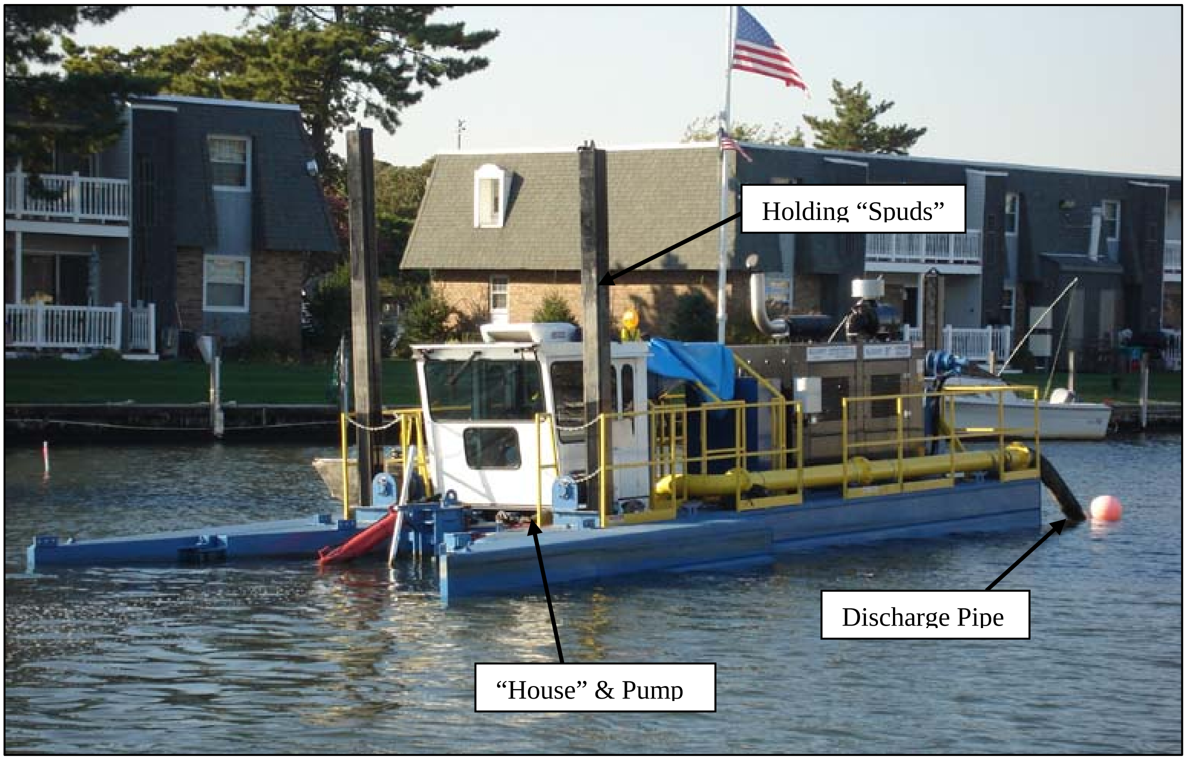


Figure 1: Small Hydraulic Dredge (Photo courtesy of Ellicott Dredges, LLC**)**

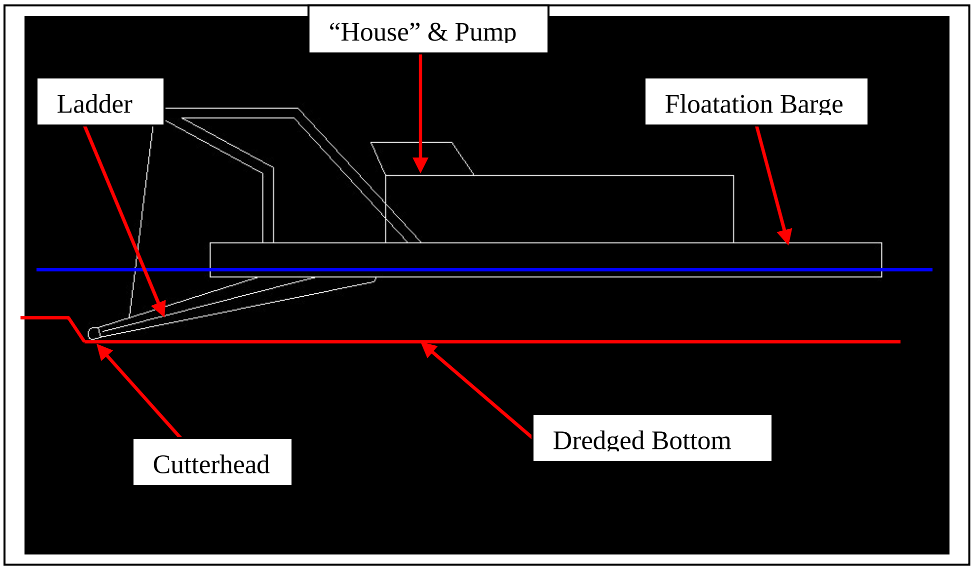


Figure 2: Simple schematic layout of Hydraulic Dredge

The hydraulic dredge consists of a floatation barge that is sized to the dredging application; in the case of Figure 1 the floatation barge would be about 10 feet wide and about 30 feet long. By comparison, the largest hydraulic dredge in the US fleet is about 66 feet wide by 305 feet long; this range demonstrates the very large spread in equipment size to suit application needs. Most hydraulic dredges are dedicated to the process of dredging; conversely some mechanical dredges may serve dual purposes, such as lifting cranes or pile driving rigs. The principal working of a hydraulic dredge is that it uses a large pump (usually located within an enclosure on the dredge - commonly referred to as a “House” as shown in Figures 1 & 2). The intake side of the pump is connected to a suction line housed inside of a long frame known as a “Ladder” (Figure 2), and the pump discharge side is connected to a flexible pipeline (Figure 1) that runs to the place where the dredged material will be deposited. At the extreme end of the ladder, is a rotating “eggbeater” type device known as a “cutterhead”. In this dredging process the cutterhead is lowered to the bottom of the waterway until it comes in contact with the bottom sediments. Upon contacting the bottom sediments, the rotation of the cutterhead acts like a paddlewheel and agitates the bottom and displaces the sediment that it comes into contact with and puts them into suspension. The sediment becomes mixed with water (called a slurry); where upon the intake port of the dredge pump, located on the ladder immediately next to the cutterhead, sucks the sediment into the dredge pump. From there the pump pushes the slurry mix to some distant destination by way of a pipeline. Pump and pipe sizes range from as small as 4” to as large as 36”. Also note in Figure 1 – the holding “Spuds” which are long steel shafts that are set into the bottom to hold the dredge in place while it is working. Spuds are the most common form of “anchorage” for any dredge – however, anchors and cables (wires) are also used – while it is not obvious from the photograph - the dredge in Figure 4 is working off of anchors and wires.

Mechanical Dredges are fundamentally different than hydraulic dredges – in that they employ some form of mechanical excavator on a floatation barge. The excavator can be a backhoe (Figure 3) or a Crane/Clamshell (Figure 4). A “Clamshell” Excavator uses a Crane (either tracked or ring mounted – as shown in Figure 4) and digging device similar to the one pictured in Figure 3, which resembles a clam shell and is raised, lowered, opened and closed using wire cables. A Backhoe excavator may use either an open “scoop” type bucket or a modified type of clamshell bucket (pictured Figure 3); the later tends to minimize spillage compared to an open-type bucket or conventional clamshell. Spillage is closely linked to “turbidity” or sediment suspension in the water column – which is a regulatory issue that must be considered in any project. An environmental issue with mechanical dredging is that “closed” or “tight” buckets are commonly required be permit – however true reduction in spillage is only accomplished when the bucket fully closes and the bucket is raised through the water column at a predetermined rate of speed (this is discussed in more detail in Parts 2 & 3).

Figure 3: Small Mechanical (Backhoe) Dredge

A word of terminology caution is offered here – in “land” applications backhoes are sometimes referred to a “Hydraulic Excavators” thus can be confused with the term “hydraulic dredges” which are completely different in function, as noted in the preceding paragraphs. One needs to be aware of the potential for confusion if one inadvertently inter-mixes the use of these terms – as they are not interchangeable. This can be particularly problematic in the area of environmental permitting - since permits must define the methods to be used for dredging as either hydraulic or mechanical. From the perspective of the regulatory authorities the terms of “Hydraulic versus Mechanical” are strictly applied as described in the above paragraphs. Thus an inadvertent mix-up such as the use of the term “hydraulic dredging” being applied to a backhoe type mechanical dredge (i.e. meaning a hydraulic backhoe excavator), when the applicant really meant to imply the use of a hydraulic backhoe performing mechanical dredging could likely be misinterpreted by the regulator as meaning “Hydraulic Dredging”. Whereupon the permit for the project intended to be a *mechanical* dredging project might be issued as a *hydraulic* dredging project. The problem is that it is normally a violation of the terms of a permit (as well as illegal) to use any dredging method that is not specifically specified by the issued permits. Thus – if such a misunderstanding were to occur on your project - at some point *after* the issuance of the permit this discrepancy would likely be discovered (usually by the dredging contractor), and work would have to be postponed or suspended until the permits could be modified. Modification of a permit usually takes a minimum of a month, but can drag out for several months depending on local policies. Also worth knowing is that regulatory agencies routinely police permit compliance by way of aerial reconnaissance, so if a discrepancy such as that described above occurs it is far better to correct it before beginning work on a project.

Figure 4: Large Mechanical (Clamshell) Dredge

Figure 5: Self-dumping material scow (& clamshell dredge to right)

The other significant difference between a mechanical dredging operation and a hydraulic dredging operation is the means by which the dredged materials are transported to their ultimate destinations. In mechanical dredging the material is almost always loaded into individual material barges or "scows" (Figure 5), and then when the barge or scow is fully loaded – it is towed to its ultimate destination and either dumped or off loaded – depending on the mode of disposal. A scow can be virtually any size, and should be sized to project requirements. Scows for traditional dredging projects range in size from 500 to 5000 cubic yard capacity; however custom made scows for small projects can be as small as 25 cubic yards.

Other types of Dredging Equipment:

While Hydraulic and Mechanical Dredges are the most common in use today, there are also a number of special types of dredges and hybrids that have their own specific advantages and disadvantages. This course will not go into these in detail, but briefly - other types of dredges are as follows:

1. Hopper Dredges: These are basically self-dumping barges, most commonly in the form of small self propelled ships that utilize a “trailing suction”, which is similar to a hydraulic dredge ladder and suction. The trailing suction creates a slurry of the sediment to be dredged in much the same way as a conventional hydraulic dredge, then pumps the dredged material into “bins” located in the ships hull, all dredging is performed while the ship it is underway at up to 7 knots. When the bins are full, the ship lifts the ladder, and travels under its own propulsion to the disposal site (usually in the ocean) where it dumps the material in designated locations. Hopper Dredges are most commonly used in ocean sites where the dredged material is primarily sand. Special adaptations have been made that allow them to literally “Spray” the sand/water mix on to beaches as part of beach nourishment projects.

2. Self Loading Mechanical Dredges: These are somewhat similar to hopper dredges, in that the dredge is mounted directly on the material barge, or bottom dumping scow. This type of dredge may be towed or self propelled, depending on the locality of the work. The dredge is normally a mechanical excavator, either backhoe or clamshell. This type of dredge is usually used in very narrow or shallow waterways, where there isn’t sufficient room for the dredge and barge to work side-by-side together. They are very common in the inland waterways and canals of Europe; conversely there are very few working in US waters.

3. Backhoe dredges that use hydraulic pumps: This is a hybrid and uses either a barge mounted crane or backhoe with a hydraulic dredge type pump attached to the end of the boom, or suspended from a cable. This system works essentially the same as a hydraulic dredge in that it uses an agitator or water jet to loosen the dredged material, and then pumps it to its intended location – for permitting purposes this is normally considered “hydraulic” dredging, as there is no bucket or

clamshell involved in the process. These are somewhat common in sand and gravel mining, and to a lesser extent in beach nourishment.

4. Portable dredges: These are available in both mechanical and hydraulic varieties. The term “portable” is applied where the dredge and/or material barges are small enough to be trucked over the road, or they can be disassembled into components that are small enough to be trucked. The most common usage of portable dredges is for “land locked” projects, or on projects where access by a waterway is very limited. Portable hydraulic dredges such as the one in Figure 1 are reasonably available and can be rented. Portable mechanical dredges are usually custom assembled for the particular project. They are usually comprised of “sectional barges” that can be bolted together to make larger work platforms, such as the dredge Figure 6b. Likewise – material barges can be either custom made or assembled from several sectional barges. If in doubt, check with a local marine contractor – they will usually know the availability and applicability of this equipment.

For more information on the varieties of dredging equipment for specialized applications one can Google “Western Dredging Association” or publications such as “World Dredging” or “International Dredging Review”.

Figure 6a: 3000 cubic yard self-dumping scow – 5’ light draft 18’ loaded draft

**Figure 6b: 25 cubic yard, very small material barge;
light draft about 2' – loaded draft about 4'**

Character of Dredging Materials:

Dredging projects normally involve working in existing waterways, bays, lakes and the like. Historically most of these water bodies were pre-existing, and as such the bottom materials are usually marine or riverine deposits. The exceptions to this rule would be man-made waterways or projects within existing water bodies that were deepened or greatly expanded beyond their original size.

Examples of marine deposits found on a typical dredging project would be fine to very fine silt, medium to fine sand, and fine gravel. Some river and coastal environments in the northern half of the US, as well as southwestern rivers may have deposits of large gravel and rounded rocks of up to 16”, or basically anything that can be displaced by a fast moving current. In the cases of marine deposits, materials are usually layered with finer fraction materials (fine silt), and intermittent loose and dense layers that vary in depth. Such marine deposits may vary in age from recent (a few months), to thousands of years. Generally speaking, the longer marine deposits have been in place, the denser and more difficult to dredge they become.

Materials that are not marine or riverine are usually very dense, and may even be cemented. Such materials might include glacial till, rock, shale, dense sand and gravels, and clay. Materials in these categories are generally difficult to dredge, and usually require more substantial equipment. Materials such as rock, cemented sand and shale often require pre-conditioning in the form of ripping, hammering or blasting.

Since the focus of this course is the environmental uses of dredging, and it is very rare that non-marine or non-riverine materials require dredging as part of environmental projects, they will not be discussed extensively in this course material. In addition, with the exception of very old industrial waterways (i.e. NY City or Philadelphia) it is rare that marine deposits placed more recently than the past 150 years are the subject of environmental restoration projects.

Figure 7a: Common Combined Sewer Outfall “CSO” Outfall, Brooklyn, NY

Figure 7b: **Typical sand, rock, mud & debris in urban waterway**

The most common soil that will require dredging as part of an environmental project will be silt and to a lesser extent sand. Such soils are common on roughly 90% of environmental projects, with silt (or mud) being the most predominant in about 75% or more of those cases. In urban and suburban areas the silt or mud that commonly requires dredging carries some level of contamination or pollutant (Figure 7 – left). These fine fraction soils usually originate from upland erosion. Contaminants tend to bind themselves to finer fraction materials (silt much more so than sand) thus if there is any source of upland contamination in the run-off generated in the drainage area, the contamination will be swept along in the process usually attached to the silty soils. The erosion in turn finds its way to some drainage way and ultimately to an outfall where it settles in the waterways in the form of new sedimentation or shoaling. In some cases shoreline revetments, rocky shorelines or rocky outwash areas in the path of drainage ways also become contaminated when contaminated materials leached through them. Such instances are not common but do occur (Figure 7b) and can make dredging by either method difficult.

Either Mechanical or Hydraulic dredging can be used for removal of sand & silt, with each having its own advantages and disadvantages. Any project having rock or large gravel is best left to mechanical dredging if water depths are sufficient to allow equipment access. This then leads to the next subject – the selection of the best suited (or least unsuited) equipment for a particular project.

Selecting a Dredging Equipment and Methodology:

There can be many factors in the process of dredging method and equipment selection, and the evaluation process is critical to the planning of a dredging project. In many environmental projects, access, contamination or debris issues can make this selection process very difficult - thus there may be no easy solutions. There are also factors of cost, surrounding neighborhoods, environmental regulation, and the quality of the finished product to consider. Each method of dredging has its own advantages and disadvantages with respect to each of these considerations, and all must be must be weighed accordingly. This is particularly important on environmental projects, and must also be viewed in perspective of what environmental regulations might be in place that could limit the selection process.

In some cases the designer must also evaluate if the best methods might be performing the work from a nearby accessible shoreline or whether the use of floating equipment is required. For shore based projects a backhoe, clamshell crane or dragline would be used providing the reach requirements are not too great. In the case of smaller land-locked lakes – draining and/or drying the lakebed may be possible, providing the underlying bottom is firm enough to support equipment. In some marginal terrain cases equipment might actually might actually be able to perform the work in “the dry” working off of wood crane mats. If a project qualifies for any of these options – the procedure then differs very little from conventional excavating – and as such will not be covered at length within this text. The discussions which follow all assume that site conditions require that floating dredging equipment be used, and that the only potential for land-side operations would be if the dredge could work close enough to shore to place the dredged material on the shore while situated in the waterway. If the water body cannot be drained and is more than about 100 feet wide, or if it is narrower than 100 feet, but is developed on either side in such a way that heavy equipment cannot operate on its shores, then floating equipment will most likely be required.

Mechanical Dredging Selection Process:

One of the largest factors separating Hydraulic and Mechanical dredging is the transportation of the dredged material from the in-situ location to its new final resting place. In the best of all possible cases loading the dredged material directly into material barges or "scows" is the most cost effective process (Figures 5 & 6). With that said, the limiting factor of low cost mechanical dredging is that most material barges or scows require between six and twenty feet of water to operate in – a few custom made portable barges may be able to work in four feet of water. Unfortunately as the available draft available for barges or scows goes down – the cost of transportation goes up – for example the cost factor between 4 feet and 20 feet of available draft can be 10 or more to 1. Thus the first thing one must look at with respect to the viability of mechanical dredging is the depth of the water body where the dredging is to take place, how far the dredging area is from shore, and how it is situated with respect to deeper waterways for purposes of material transport. Many environmental dredging projects are situated in waters less than five feet deep, and therefore due consideration must be given to adequate floatation for the dredge and its support equipment. While the required floatation for a small dredge (i.e. the type shown in Figure 3), might only be 3 feet, considerably more water is required for the material barge or scow and the tow-boat(s) that must move them around. Depending on the size of the dredge, the minimum draft for an inboard powered workboat would be about four feet, likewise even the lightest, shallow draft material barges typically require at least 1 to 2 feet of draft when empty (usually more), and require at least 4 feet of draft when loaded to carry any appreciable payload. Thus as a practical matter, if finished water depths are to be less than five feet deep – conventional mechanical dredging is probably not the best choice. There are a few exceptions to this – and that would be if there were shallow draft self loading dredges available as described in the preceding section. However, before considering such an option, one would be well advised to check with local contractors on the availability of such equipment – as it is not commonly available. Even if the equipment is available, the designer should seek the advice of someone familiar with this type of equipment before preceding with a design that "locks-in" equipment that has limited availability. There are also a number of other issues, such as the ability of work boats to move material scows around on the site, access and bridge restrictions, availability of off loading sites, and an abundance of other issues to be considered and worked through. Another issue that must also be considered is the requirement to regularly exchange scows or barges when they become full. This is to say – once a material barge is loaded to capacity, it must be moved out and an empty replacement brought in. Scows are usually quite heavy, and even shallow draft work boats must use full power to move them into position. This issue alone creates a whole other set of potential problems – this is because workboats under full power generate very powerful forces from their propellers known as “wheel wash”. If the water is shallow - wheel wash can blow craters in the bottom and will also generate huge plumes of turbidity in the process, especially if the bottom materials are soft. If these boats have to push a barge through a dredge area (which they normally would) this means that they will likely create excessively deep furrows along their paths from the wheel wash, and at the same time could create shoals elsewhere from the materials displaced by the wheel wash. If the site contains contaminated sediments – such disturbances of the finished dredged areas could easily cause serious problems such as cross - contamination of dredged and undredged areas of the site or creation of serious turbidity issues.

Taking all of the above into consideration and proceeding under the assumption that a water body does have sufficient working water depth; the following are the advantages of mechanical dredging:

1. The dredged material retains much of its in-situ density, generally increasing in volume no more than about 10 to 15% during the first handling of the material from the waterway into the barge or scow. This also means that there is minimal introduction of water to the mix, which is beneficial if the dredged materials are seriously contaminated, or if turbidity is and issue (which it most always is).
2. If appropriate care is taken - there is usually only a small volume of excess water generated during the loading of the barge or scow (see figure 5) – usually a maximum of 30% of the volume dredged. In fact – in cases where the discharge of barge overflow back into the waterway is prohibited, the barge can sometimes retain all of the excess fluid. The dredge’s production cycle also directly affects how much excess water is brought up with the bucket – as well as the introduction of turbidity into the water column. With all of that said however, and with respect to towing barges with large percentages of free standing water – appropriate precautions must be observed during towing or moving such barges as they have a tendency to capsize in rough seas.

3. The development of what are called “water-tight” clamshell buckets, (commonly referred to as “environmental buckets”) can reduce the spillage during the dredge cycle, as well as reducing the turbidity that occurs during dredging. This requires the slow withdraw of the loaded clamshell through the water column as well as the careful movement of the loaded bucket from the point where it clears the water to the location of the waiting scow. The two photos in Figure 8a and 8b show an un-staged comparison between the “environmental” and conventional type of clamshell buckets once they exit the water en-route to the scow. It can be readily observed that the “environmental” bucket (Figure 8a) generates much less overflow – which would in turn create much less turbidity. However the reduction of turbidity when the bucket is traveling thorough the water column is quite another matter – and is directly related to cycle time. That is – the faster the loaded bucket is extracted – the higher the turbidity generated.

Figure 8a: An environmental clamshell bucket dredging soft mud in an industrial waterway

Figure 8b: A Conventional Clamshell "round nosed digging" bucket dredging sandy material – note high volume of spillage

However the slow cycle time required to reduce turbidity comes with a price (literally), because while a dredge is operating in a full "duty cycle" with an environmental bucket there is still a considerable volume of seepage that is related to the velocity with which it is traveling (albeit considerably less than with a conventional bucket). Thus, in order to realize maximum effectiveness of the environmental bucket, and minimize turbidity control - the cycle time of the dredge must be slowed considerably, normally on the order of 1/5 of the speed of normal lifting cycle. This – in turn dramatically increases the dredging costs, and as a practical matter is difficult to enforce with contractors.

4. Mechanical dredge production is normally affected by debris or difficult digging materials (such as rock or heavy gravel), but in most cases the condition is not as problematic as the same condition would be with a

hydraulic dredge. As such, Mechanical dredging of industrial or urban waterways can be more cost effective than hydraulic dredging with the proviso that adequate water depth must be available. With that said – the presence of debris in the water body (Figure 7b) will commonly negate most the turbidity reduction benefits of the environmental bucket – because it can lodge between the closing surfaces which usually prevents the complete closure of the bucket.

5. The rate of production when dredging in sand or silt is usually comparable to softer materials, although in some cases a predominance of sand may require the use of a smaller, heavier bucket, which in turn slows production and makes it potentially more expensive to dredge. There are trade-offs however – in that sand usually holds fewer contaminants, and dewaters much more readily, thus is more readily disposed of or re-used.
6. Grade control with either clamshell or backhoe dredges is reasonably achievable, provided up-to-date electronic control technology is utilized. Backhoes are more readily adaptable to electronic grade control devices – and as such these devices are more common and readily available.
7. Environmental clamshell buckets offer geometry and software systems that have proven very effective in producing flat uniform finished grades, much more so than conventional clam shell buckets which tend to leave a very irregular dredged bottom condition.
8. If the dredged material must be stabilized (dewatered) for trucking or for purposes of its final disposition, it can normally be done right in the material barge before off loading, and in reasonably high volumes. Stabilization is usually accomplished by mixing lime, kiln dust and/or cement to the wet mix – then allowing it to air dry.
9. If the dredged material is uncontaminated or otherwise suitable for open water disposal – the barges or scows can be transported long distances for disposal at very reasonable costs.

There are a number of disadvantages to Mechanical dredging – which many or may not preclude their use on a particular project.

1. Site access is critical for a successful project. The route to and from the proposed work site and the disposal site or off-loading site must be checked very carefully in the design evaluation process. The rule of maritime transportation is that the narrowest width, shallowest draft,

and lowest overhead clearance along the path control the entire route. To assess these conditions accurately, the entire route must traveled (preferably by water), and carefully checked for bridges, overhead wires, overpasses, obstructions and shoals. Navigation charts carry most of this information – but they are not always up to date, especially in urban areas. As an example the bridges in Figure 9 were shown on navigation charts as "opening", however in checking with local boat operators – the bridges had been inoperable for almost 10 years.

2. Shallow draft waterways have already been discussed; however the importance of this issue cannot be emphasized enough – on a critical access project it is normally worthwhile to perform a sounding survey of the transportation route just to be sure that adequate water depth is available.
3. If dredged materials must be transferred from one barge to another, or from barge to shore while still in a wet (unstable) condition, the transfer process can unavoidably cause considerable spillage. This is because once the soils have been initially dredged and placed into a barge, any further re-handling only destabilizes and adds more water to the mix which is turn makes them much more susceptible to spillage and splatter. Unless the transfer is done very carefully, and under very close supervision spillage can easily create a whole new dredging issue at the transfer location. This is a factor that must be carefully considered when permitting and planning a project, and any transfer locations should be designated on the permit plans. This is obviously becomes a critical factor if the materials are contaminated, because it could create a whole new area requiring remediation at the transfer site. The best solution to the spillage issue is to find a way to stabilize the soils before they are transferred, this typically involves the addition and mixing of fly ash, kiln dust, lime and/ or cement into the wet mix while they are still in the barge. Oversight of such an operation is absolutely necessary to be certain that it is carried out properly. Needless to say – this process can add a cost to the project – usually about $10 to $50 per yard depending on circumstances.
4. Low overhead power lines at a jobsite can also be a problem; there are strict safety rules that apply to how closely cranes and backhoes can work to power lines.
5. Caution must be exercised with respect to towing material barges or scows that contain large amounts of free standing water. This happens when environmental regulations prohibit discharge of the excess water

that accrues while the scow is being filled. Large amounts of free water can make a barge very unstable – and roll-overs have occurred, particularly while they are under tow, or during storm events. This is particularly problematic when the barges must be towed through open water en-route to disposal sites, especially where wave action can occur during inclement weather. The Coast Guard and US EPA treat accidental spills of almost any magnitude as unauthorized dumping. Loss of dredged materials (accidental or not) in any waterway outside of the permitted areas is a Federal crime and carries serious penalties, and while such penalties are usually the burden of the contractor – the engineer can also become exposed to liability in certain circumstances. When in comes to this issue – erring on the side of caution is advised.

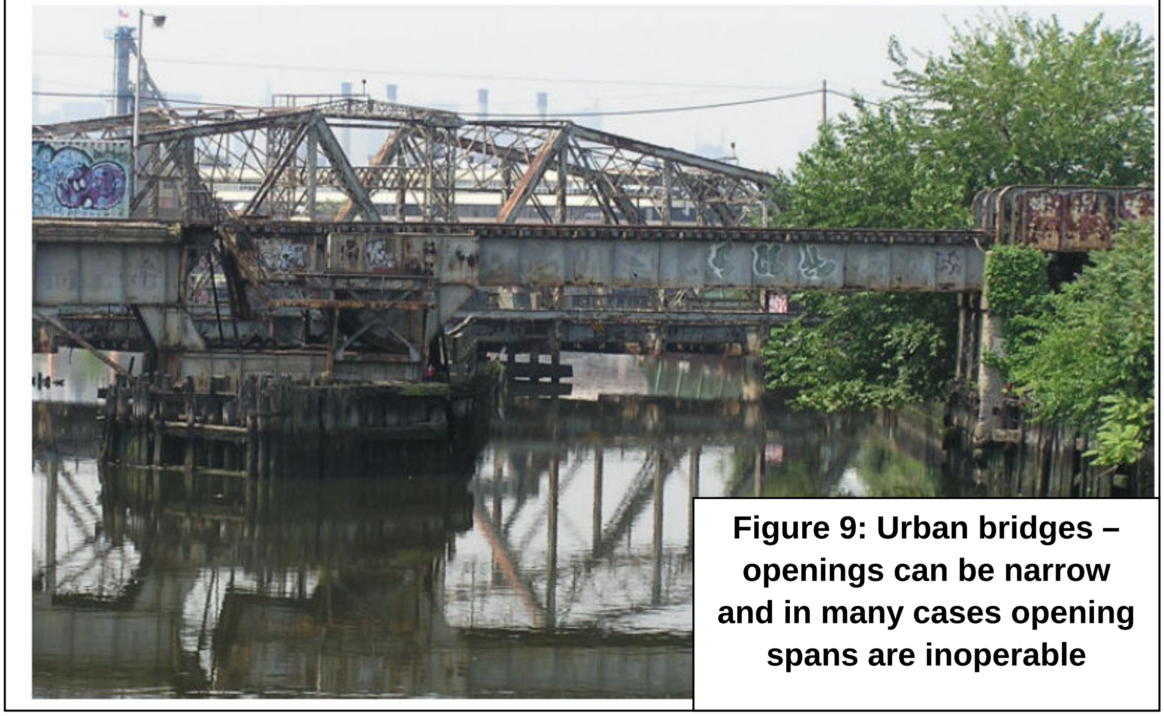


Figure 9: Urban bridges – openings can be narrow and in many cases opening spans are inoperable

Hydraulic Dredge selection process:

Because hydraulic dredges come in so many shapes and sizes, shallow water depth at a dredge site is usually much less problematic than with mechanical dredges. Small and medium portable dredges are commonly available in pump sizes from 4” to 16”. Conversely the availability of larger hydraulic dredges can be sporadic - thus finding available hydraulic dredges with pipeline sizes over 14”, or with the ability to work in over 20 feet of water can be difficult and availability can vary considerably depending on market conditions. A small portable dredge can operate in as little as two feet of water, and normally does not require much in the way of supporting vessels. However, there is a large trade-off in the transport of the dredged materials to remote sites. That is to say, in order to get the dredged material to a consistency where it can be pumped through a pipeline over long distances, the dredge must essentially mix the in-situ material and add water in sufficient proportions to produce a water mud/sand mix (commonly called a "slurry"). The minimum added water component is in the realm of 5 to 1 for silt, and 10 to 1 or more for sand. That is to say that five or ten parts of water must be added to every one part of the in-situ mud or sand in order for it to become a mix that can be pumped by a dredge, coarse sand and clay usually require more water. The trade-off is that once converted to a slurry, the dredged material can be pumped over reasonably long distances (one to four miles is not uncommon) with minimal impact to the environment.

Figure 10: A 10" Dredge pipe routed through field (left) – 12" Dredge discharge on beach nourishment project (right)

Sandy dredged soils are among the best suited for hydraulic dredging, and they can also present several alternatives for beneficial re-use. The nature of the discharge from hydraulic dredging process is such that it becomes a natural processing plant for segregating soil types (Figure 10 – right). This attribute is particularly beneficial for beach nourishment and is why hydraulic dredges are the preferred method of re-use (Figure 10 - right), even if the sand gravel component of the material is discolored with some residual silt – it usually washes and naturally bleaches itself in a relatively short time. In many cases "diking" to retain the soil is not required – but this is generally a site specific design issue. For non-beach projects - even where there is a considerable silt component – the sand and gravelly components always become segregated at the end of the disposal site closest to the pipe discharge and can be easily “mined” and reused. If the originating water body is salt water, the salt generally washes away in a relatively short time opening the door for numerous re-use or resale possibilities. This is also beneficial if the in-situ dredged material is somewhat contaminated – as the contaminants generally bind to the silt component and leave the sand and gravel relatively clean. Depending on the severity and nature of the contamination, this feature generally allows the sand/gravel component to be beneficially re-used as fill on specific restoration/ remediation projects where low level contamination is not an issue (i.e. “brown field” restoration, or as road base materials). This is one of the major regulatory advantages of hydraulic dredging, because in recent years there has been increased emphasis by regulators on the beneficial re-use of dredged soils. Thus the natural segregation process of the hydraulic dredge lends itself very readily to such re-use, whereas in-situ or mixed soils that result from mechanical dredging projects are much less readily adapted.

Dredged materials that are primarily silt are another matter altogether and unfortunately on most projects their predominance is usually the rule more than the exception. When silt, which is already of muddy consistency, is mixed with another five parts of water to become a slurry mix – it becomes (literally) not much more than very dirty water. Thus when it gets to its final designated location by pipeline there are a number of containment and drying issues that must be dealt with. Depending on local climate, silty dredged material can take weeks or months to settle and dewater, and typically requires a large dedicated site for this to take place (Figure 11, 12a & 12b). Once the material finally dries it takes up a very cracked appearance – thus even when dry it usually re-absorbs water with relative ease (Figure 13). As a practical matter, once a site has been used as a Dredged Material Management Site (DMMS), it has limited re-use unless steps are taken to restore the area, regrade it and stabilize the soils for the longer term. The sizing of a DMMS for proper natural water separation and drying is a calculation that requires considerable experience, but an example of a suitable site is shown in Figure 11. This site shown was designed to hold about 120,000 cubic yards of uncontaminated river sediment. The general size of the property can be approximated by referencing the size of the nearby houses.

Figure 11: Typical DMMS, (circle) will hold about 120,000 cubic yards

Figure 12a: Typical DMMS, before the start of dredging

Figure 12b: – Typical discharge of silty material from pipe

Figure 13: Typical DMMS, after dredging and extended period of drying

In most urban and even suburban areas finding enough space for a natural dewatering site can be a formidable task, and even if such a site is available there are many issues to face getting a DMMS permitted for disposal of silty dredged materials. Because of these issues the designer must be prepared for local opposition during the permitting process. Typical problems are:

1. Odors of decaying organics & occasional attraction of hoards of scavenger birds.
2. Seepage of salt or contaminants into the soil and underlying aquifers.
3. Unsightly appearance for extended periods of time – until restoration is possible.
4. Rehandling and the accompanying truck traffic if the materials must be transported to a secondary final destination.
5. Cost of site restoration required to appease local interests.

Worth noting is that when the dredged materials originate from fresh water sources they can be somewhat less problematic than those for dewatering of materials from salt water sources. If the soils originate from fresh water sources and are relatively uncontaminated they can normally be reused as top-soil provided that they are remixed with sand for stabilization. Historically, dredged silt with low levels of contaminants has been successfully reused as topsoil for a variety of industrial or urban restoration projects. Other possible re-uses for more severely contaminated soils involve mixing in admixtures to stabilize the contaminants and using them as non-structural fill. (It should be noted that projects involving re-use of contaminated soils is normally a specialty – requiring a certain level of experience and expertise to attain acceptable levels of final soil stability that will not cause re-contamination of the environment).

If a large site is not available or if local opposition or permitting conditions appear to be too formidable to overcome – the next best alternative is chemical/ mechanical dewatering, or a related method known as “geo-tube” dewatering. Either method will add a cost to the project, generally in the range of $15 to $40 per cubic yard (2009 costs). These methods of dewatering are somewhat similar in that they normally require the addition of “polymers” to the slurry mix at the discharge end of the pipeline to accelerate the water separation process. The polymers reduce the time required for drying from a period of weeks or months down to timeframes measured in minutes or hours. The rate of accelerated water separation depends on the type and amount of polymer added, as well as the separation process being used.

Another simple alternative method is the “geo-tube bag” dewatering method; however this method also requires more space. “Geo-tubes” are large porous bags made from geo-textile fabric. The fabric is sewn into the shape of large bags which generally lay flat until filled. Sizes range from 6 to 12 feet wide and 30 to 50 feet long. This process can be used with or without polymers, but generally works much more effectively with their use. For best results the polymer doses should be carefully monitored to avoid over or under dosing the mix. Trailer mounted computerized dosing systems have been developed for this purpose and have become readily available; they usually pay for a large percentage of their cost in polymer savings. The geo-tube dewatering method usually requires 2 to 8 weeks for the soils to reach an optimum dewatered condition, after which the bags are either buried in-place, or cut open and loaded on trucks for transport to another location. This process has also been adapted to dewatering in the hoppers of material barges where no land space is available for processing. Geo-tube dewatering can be about half the cost of mechanical dewatering – but still requires considerable space, usually only about 20 to 25% of the space required for natural dewatering.

The next most commonly used method is Mechanical Dewatering, which requires the least amount of space to accomplish, and is by far the least intrusive of all the methods discussed so far. Depending on production needs, a plot of land (or barges) 100’ by 200’ can handle a dewatering operation that can process from 400 to 800 cubic yards per day. This is the most common method for dealing with contaminated soils, since the dewatered soils can be loaded directly on to trucks or barges for transport. The photo on the next page is such an operation, note that properly managed this method eliminates 98% of the spillage issues involved with re-handing wet soils as compared to the spillage shown in the photos of mechanical dredging in Figures 5, 8a & b. This is also the best solution for dewatering in areas that are heavily urbanized or populated because the process is so controlled – there is little spillage and usually minimum of mud “tracking” by the trucks involved. In addition, because of the small space involved - odor control systems can easily be deployed.

The only difficulty that occurs during the mechanical dewatering is the disposition of the excess water that results from the processing. One way to remedy permit issues that may come up on this issue would be by piping the return water back to the originating water body. Some times this becomes a permitting issue, because the return water in some cases can be quite turbid (300 to 500 mg/l), and as such may be precluded from discharge in any random location. In some cases the easiest solution is pumping the process water all the way back to the vicinity of the dredge – which is usually isolated with silt booms.

Barge loading operation of dewatered dredged sediment – note that there is virtually no spillage

Another permitting issue that will come up in either geo-tube or mechanical dewatering is the toxicity of the polymers on marine life, in such cases it is best to consult with one or more manufacturers of polymers for the best non-toxic selection for your application. This normally requires obtaining a mud sample, and sending it to a polymer supplier for testing.

There are a number of disadvantages to Hydraulic dredging most of which have been discussed – however the following is offered as a summary:

1. The process of hydraulic dredging mixes a considerable amount of water with the in-situ dredged material. As such, it can be problematic and costly to dewater the soils once they reach their destination, especially when the soils are primarily silt, or if there is contamination involved.
2. It takes considerably more expertise to properly perform hydraulic dredging as compared to mechanical dredging. Allowing an inexperienced

contractor to go through the learning process on your project is not advised.

3. Debris and rock can be particularly troublesome using this method, it is very important for the designer to carefully check the site for materials of this nature. Failure to do so will most always result in either delays or disputes with the contractor.
4. The pipeline must be continually monitored for breaks or leaks. This can be very problematic if portions of the pipeline are underwater along the route. Breaks can occur for a number of reasons, being hit by passing vessels is one of the most common. A break in the line can create a large mound of sand or mud at the location of the break, as well as serious turbidity issues – which like a scow capsizing, is subject to Federal laws and can be subject to criminal charges. Therefore it is very important to always have precautionary language in the contract documents requiring continual monitoring of pipelines while dredging is in progress, and insist on the strict implementation of those precautions.

Grade Control and Survey – before, during and after Dredging:

The most common misconception in dredging is that the grade control process resembles upland earthmoving projects. The nature of dredging is such that it is at best very imprecise process, primarily because the work is, by definition - performed underwater. As such progress and finished grade condition is not visible by eye, which is to say – a dredge operator is working strictly by the “feel” of the equipment and what he perceives based on the on-board control systems. Even with the advances of electronic monitoring and grade control devices – this part of dredging remains more of an art than a science – and the quality of finished dredging projects can vary considerably depending on the skill of the dredge operator. Basically the only true way to verify if underwater excavation is conforming to the required grades is to perform a survey of the work area as the work progresses. This means that the only way to truly see how work is progressing underwater – is to continually perform verification surveys. Underwater survey (termed “bathymetry” or “hydrography”) is a specialty service and is in today’s world very different from basic “land” survey. Depending on the nature of the work – the frequency for performing surveys can range from every few hours to every few days. Generally speaking the greater the time increment between surveys, the less accurate the finished dredged product becomes. This is mostly because even the most experienced dredge operator needs real world feedback on his/her work, and the more frequently they get this feedback – the better their final work product. Verifying grade and getting an accurate picture of the finished bottom condition has always been a difficult and expensive process. Proper project design of a dredging project typically requires a survey of the existing water depth conditions (known as a “Condition Survey”). Then once the project is permitted and a contractor is secured to perform the work, the Federal dredging permit requires that a “Pre-Dredge” survey within 60 days of the onset of dredging operations. Once work actually commences numerous progress or check surveys should be performed (normally performed by the contractor). Independently, several formal progress surveys (normally done by the inspecting engineer) are usually required for payment purposes normally on a monthly basis. The frequency requirement for the “progress survey” component varies depending on the scope and complexity of the project. In addition, one or more formal “post dredging surveys” may be required in order to assure the project sponsor that the work has been completed in accordance with the contract. Fortunately advancements in electronic sounding methods, electronic positioning, computers and software have made the survey task much more sophisticated and accurate, and to a limited extent more user friendly.

There are a number of ways to survey underwater ranging from the “lead line” method – which uses of sounding poles or discs to perform random spot checks, to “single beam” electronic sounders (which can produce 10 to 20% bottom coverage), to “multibeam” sounders (that can produce 100% bottom coverage). The cost of these surveys typically escalates with sophistication and the percentage of bottom mapping coverage required by the project. This subject is so important that the US Army Corps of Engineers, who is the largest single contracting source for dredging projects in the US, has written a whole manual on the subject (EM 1110-2-1003) which is about 2” thick. Because of the depth and complexity of this subject it will only be discussed here in general terms.

The simplest method of surveying is the “lead line” method, which is also the most basic. This method requires a boat and the use of a sounding pole or sounding disk and some sort of positioning system (preferably survey grade GPS).

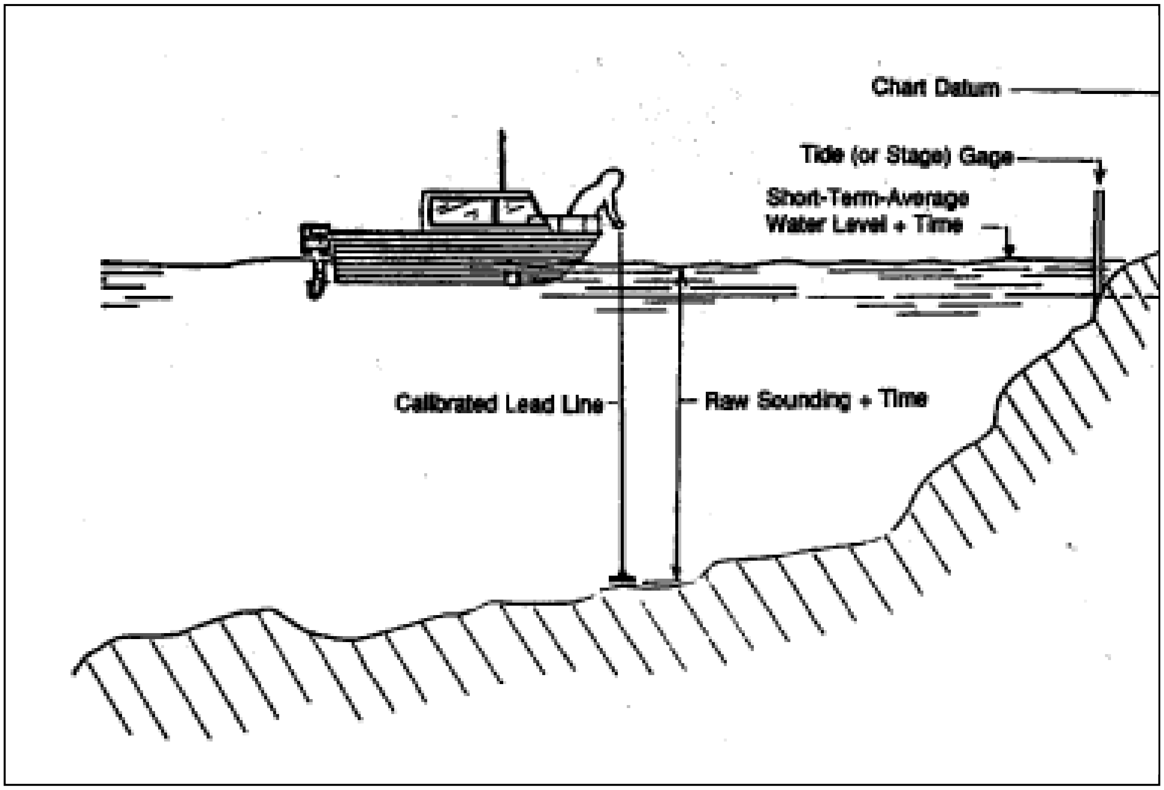
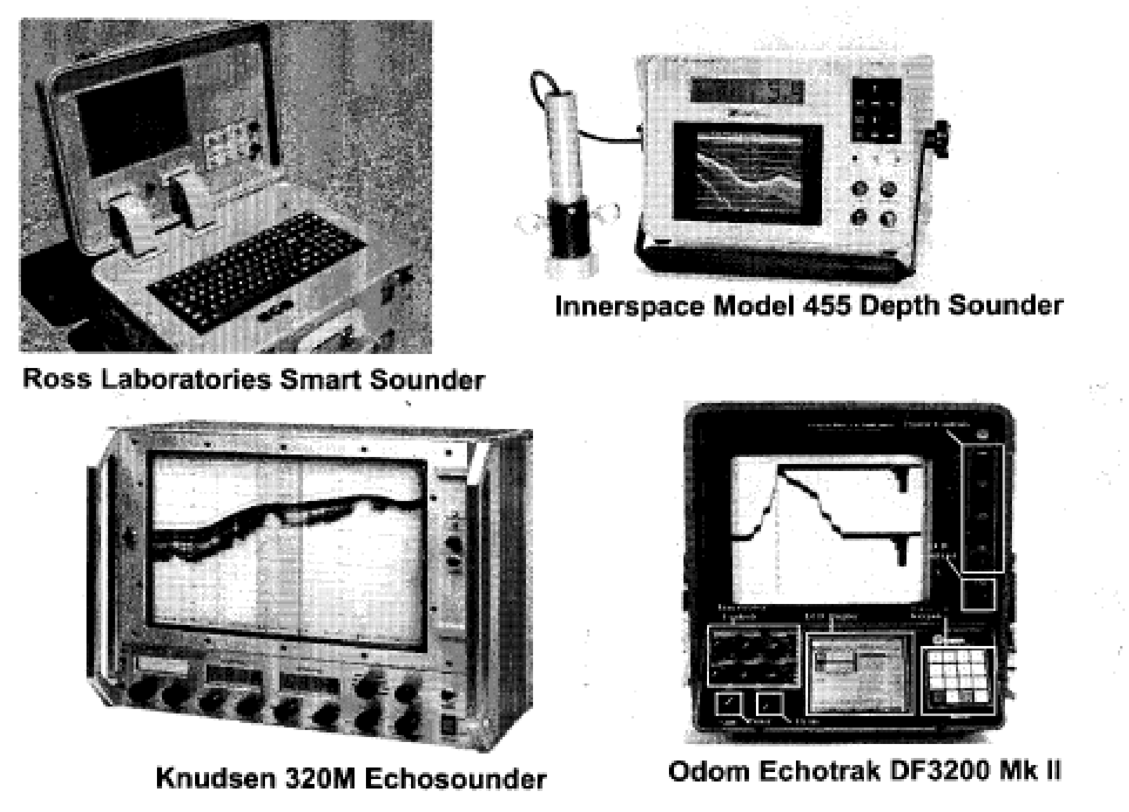


Figure 14: Typical survey using a boat and sounding disc (taken from USA COE EM 1110-2-1003)

Lead line sounding is simply the process of taking a manual measurement of the distance between the water surface and the bottom at gridded locations, determining the position by GPS or some method of conventional survey, and then recording the sounding either electronically or in a field book (Figure 14). At the conclusion of the survey the individual soundings are plotted and the progress of the work can be evaluated. This method of survey is generally the least expensive; however it generally leaves a lot of the work area unsurveyed. Thus it tends to be the least accurate method and it is the most prone to error. As such, this method is not recommended for any projects where grade control is considered to be a significant factor.



Ross Laboratories Smart Sounder

Innerspace Model 455 Depth Sounder

Knudsen 320M Echosounder

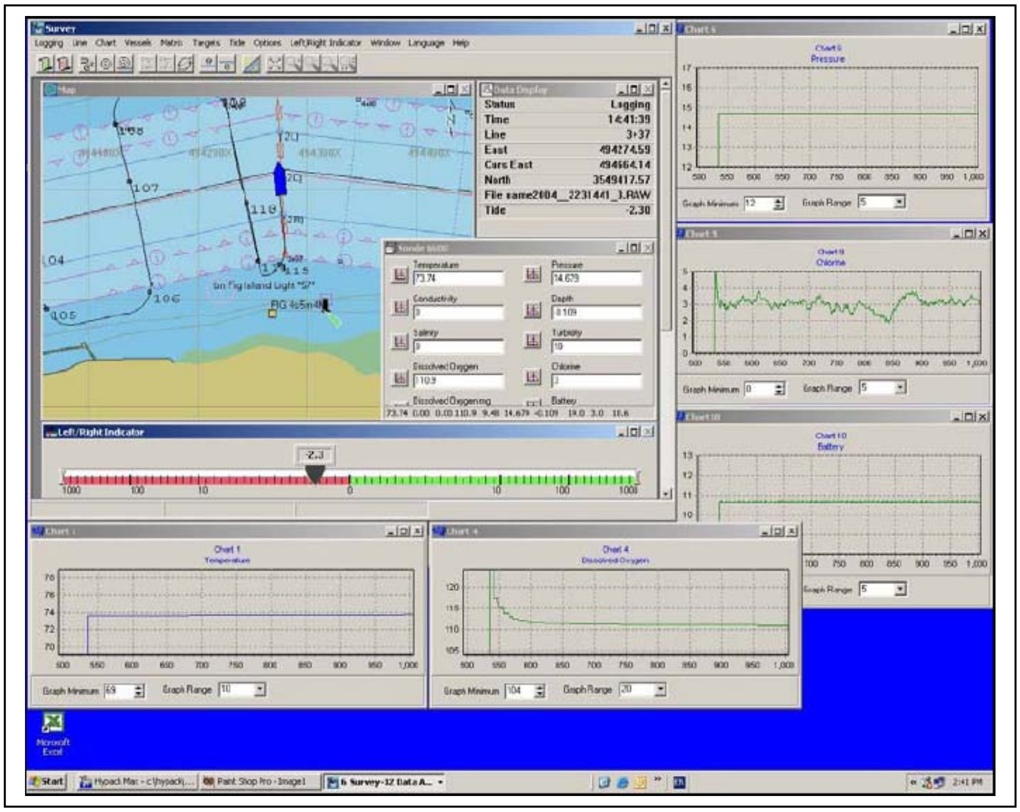
Odom Echotrak DF3200 Mk II

Figure 15: Typical "single beam" sounders

(from USA COE EM 1110-2-1003)

The most reliable methods of survey employ some form of electronic depth sounder (Figure 15), which measure water depths directly under the boat. They typically record water depths continuously, and plot a chart as a continuous record of the depths, then in the process, they generate a digital depth reading which can be linked to a computer to log the information and correlate the depths with the position of the boat.

A typical surveying operation that utilizes a single beam sounder also employs a Survey Grade GPS (Accurate to within two feet or less), and a computer with software that provides guidance for the boat operator as well as logging and displaying the survey progress (Figure 16). A single beam survey will typically run the boat in a series of regular offset lines (resembling a "plowed field" - see upper left of Figure 16), which can vary in spacing from a little as 5 feet to as large as 200 feet.



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Salinity 0
Turbidity 10
Dissolved Oxygen 110.9
Chlorine 3

73.74 0.00 0.00 110.9 9.48 14.679 -0.109 19.0 3.0 10.6

Figure 16: Typical computer software for "single beam" surveys
(Courtesy of Hypack.com)

Given that most underwater surfaces are irregular, the separation distance of the survey line offsets greatly affect the completeness and accuracy of the finished survey. There are two types of lines used (1) "cross" lines that are perpendicular to the channel alignment, and (2) "long" lines which are run parallel to the channel alignment. Depending on complexity and the nature of the dredging work, typical cross line offsets range from 10 feet to 50 feet, resulting in 10% to 40% bottom coverage; in most cases the survey "long" lines are spaced at 50 foot offsets, however if a higher level of detail is required the offset can be as little as five feet. Conducting underwater hydrographic surveys is a specialty that requires a fairly high level of training and experience. They should not be undertaken unless the person in charge has been professionally trained in this field, especially with respect to the requirements of calibration and quality control. Single beam surveys are generally suitable for most dredging projects unless 100% bottom coverage is needed to assure much more precise and complete grade control on a project.

The next higher level of underwater survey is known as “Multibeam” which uses an array of beams to measure water depth in a very close grid, this grid can be as little as 10” x 18” or as large as 4’ x 4’. As of this writing most multibeam systems require a substantial and dedicated survey vessel and a sizable monetary investment, ($200,000, usually more), however as with anything electronic, smaller less expensive packages are working their way into the market. With that said, these smaller packaged multibeam units are still quite expensive – and still require significant set-up and lengthy calibration time. The time normally required for installation and calibration of even the simplest of multibeam systems in a “transient” vessel presently is not conducive to use in a non-dedicated boat – thus truly portable systems are not seen as something that will appear in the near future.

Figure 17: Typical dedicated survey vessel
(from USA COE EM 1110-2-1003)

A Multibeam Survey System requires a the Multibeam Echo-Sounder, which is the most expensive component, as well as one or two computers to keep track of the data (depending on the sophistication of the system); also a survey grade GPS, preferably with RTK accuracy which give true positions in the realm of plus or minus three inches, a digital compass to keep track of the boat heading, and a motion sensor (called a Heave-Pitch-Roll sensor), to track the attitude of the boat in real time. Obviously with all of this equipment and the sophistication of the system as well as the potential for error – these systems are best left to those who have been thoroughly trained in their use.

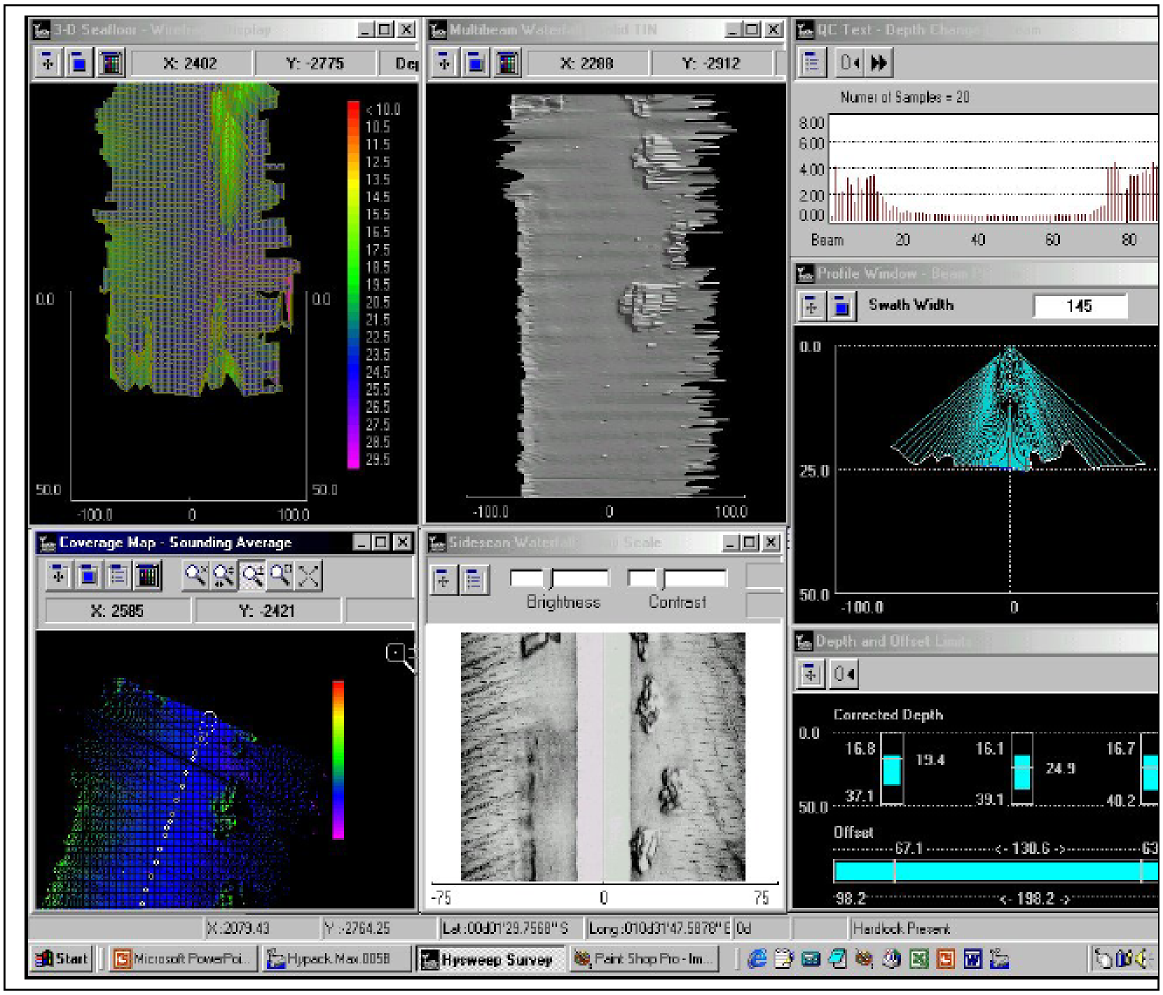

Figure 18: Typical computer software for "Multibeam" surveys
(Courtesy of Hypack.com)

Multibeam surveys usually carry a price tag of two to four times the cost of single beam surveys, but as Figure 19 demonstrates – on complex projects they are usually worth the extra cost. These systems are not without their shortcomings however, and the most significant drawback is that they are generally not suited for work in less than 10 feet of water, and 15 to 20 feet of depth is preferred. They are also very susceptible to “multipath” errors when working near large structures – such as bridges, and are also prone to picking up “bottom clutter” which is a term that refers to false readings that emanate from any number of sources. Areas that are particularly problematic are those associated with fast river currents or heavy commercial vessel traffic.

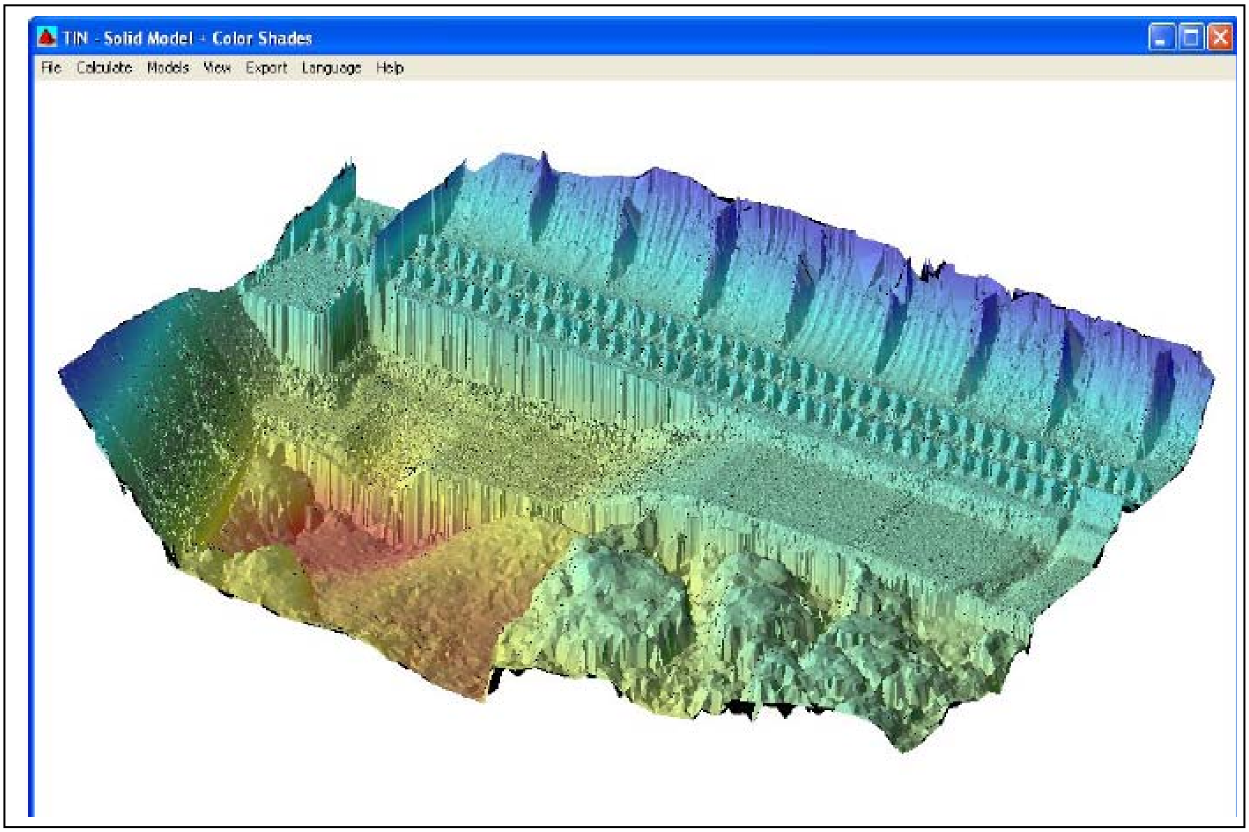

Figure 19: Level of survey sophistication available with multibeam

(Courtesy of Hypack.com)

Course Recap:

In Part I of this course we have discussed the basics and a few of the complexities of Dredging. Upon completing this course the Engineer should have a basic understanding of the two basic types of dredging as well as the primary advantages and disadvantages of each method - these two types of dredging are:

1. Mechanical Dredging
2. Hydraulic Dredging

In addition the Engineer should now have a basic understanding of:

1. The basic differences between the two dredging methods
2. An understanding of how each method works
3. The advantages and disadvantages of each method
4. The general types of soils that are normally dredged in the marine environment.
5. The general types of equipment and the logic related to equipment selection
6. A few of the common pit-falls that can be encountered in a dredging project.
7. A general understanding of the requirements of material re-handling, management and disposal.
8. An understanding of the methods and equipment used for survey and controlling grade on dredging projects.

Once the Engineer has developed an understanding of these components, he or she should be in a position to go on to study other levels of dredging design. Other available Continuing Education Courses available on this site go on to undertake other areas of environmental restoration, Part 2 discusses the processes of contaminated soil removal and remediation; and Part 3 covers the basics of Beach Nourishment and Wetland/ Habitat restoration.