HOW ACCURATE IS ACCURATE?

The History, Present State & Future of Dredging Accuracies & How it Relates to Dredging the Contaminated Environment

Authors: John A. DeRugeris, P.E.
Carlos G. Peña, P.E.
CLE Engineering, Inc.

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John A. DeRugeris, P.E. (1)
Carlos G. Peña, P.E. (2)

ABSTRACT

Dredging of contaminated sediments is an expensive and sometimes protracted process. A number of innovative positioning techniques and devices have been created to increase the accuracy of the dredging process and to meet the stringent environmental needs. The result of this effort has created a cottage industry in the development of software and hardware to provide dredge positioning and tracking of dredge operations. The dredging industry has made a giant leap forward in the past decade with technology and the question becomes how accurate can we be, have we really become more efficient and has the cost of dredging been reduced due to these advancements?

The ideal dredge system working in a contaminated environment would be able to efficiently identify and locate the contaminated sediments and excavate the sediment to the design envelopes with a minimum of detrimental turbidity. Yet, with every passing year as the equipment and software becomes progressively better, the problem of transporting the accuracies and capabilities of positioning systems from the theoretical ranges to real operational dredging limits remains more of an art than a science. Further, since each project has its own specific issues, and consequently its own unique field problems in attaining target accuracy and meeting a dredging envelope, there seems to be no set of menu driven parameters wherein one can seek a series of set solutions. Once a system is established, the reality then becomes that no matter how sophisticated the equipment, it is only as good as the people who design, program, maintain and operate it. Maintaining a system at the accuracy levels it was originally designed for over the life of a project is often more of a challenge than the initial mobilization. Thus on many projects, only a portion of potential new dredge technologies are ever realized.

This paper will evaluate the history, present state of dredge positioning systems and offer a possible glimpse into the future for possible advancements. It will also discuss equipment selection and deployment methods, and how installation and operation affect reliability and maintenance. There will also be an evaluation of realistic expectations, the pitfalls that creep up along the way, and ways to get the most benefit from recent advancements in the form of efficiency and the cost of dredging projects.

(1) President, CLE Engineering, 15 Creek Road, Marion, MA 02738
(2) Vice President, CLE Engineering, 15 Creek Road, Marion, MA 02738
(2) Past President, Boston Society of Civil Engineers, One Walnut Street, Boston, MA 02108

HISTORY

For thousands of years dredging projects extending back to the Fayum Reservoir constructed in 5,000 BCE, Egyptians utilized basic geometry to define the dredge areas, range poles to align and orient excavations and lead lines or calibrated rods to measure depths. Four thousand years later in the era of Galileo maritime navigators made the next major step forward in the form of the sextant and compass. Over the ensuing four hundred years methods of measurement and land survey advanced by the introduction of the transit and distance measurement devices gradually improved land survey, but up through 1970 such equipment had found little acceptance within the maritime market. The only true marine "electronic" positioning system known as Loran was far too inaccurate for anything other than very general offshore surveys, and surprisingly the device that the Corps of Engineers relied on through 1985 on for most of its navigation surveys remained the sextant. Further "lead line" surveys are still quite common today. The advent of reliable microwave positioning units and theodolite based range-azimuth systems, and general use of acoustic fathometers increased the possible accuracies for dredging projects through the 1980's and into the early 1990s. These systems had general position accuracies of approximately one to three meters (favoring the latter), but required extensive networks and the remote transponders required constant maintenance. Water depth measurement systems operated on batteries, and had to be checked regularly for built in inaccuracies caused by battery drain, or paper shifting. These systems required personnel who were extremely skilled and attentive to obtain consistent results, and even so highly erroneous data was not uncommon.

Since its introduction in the early 1990s, GPS went from an erratic unreliable second choice of surveyors, to one of the most important advancements of the century. At its introduction when only a handful of satellites were available, and then only at odd hours, real time accuracy of five meters appeared to be about the best one could do. Yet in five short years, before the turn of the millennium, real-time kinematic systems, with consistent accuracies of under two centimeters were becoming the surveyor and contractor's tool of choice. Meanwhile depth measurement equipment has become more and more reliable (albeit much more expensive), but now has stabilized power systems, electronic charts, multibeam swath capability, and the ability to classify both sediment types and thicknesses with increasing reliability. All of this improved the quality of the dredge area mapping process by many orders of magnitude, and the systems have become increasingly user friendly.

Meanwhile, dredging contractors also capitalized on the more modern technology for larger dredges, but technology lagged severely on smaller dredges. Indeed until the past twenty-five years, only a few small dredging projects have utilized anything more technically advanced than that of the Egyptians. Ironically, it seems that the majority of contaminated material dredging projects have been more suited for smaller dredges, primarily because of restricted access or the perceived potential for more surgical dredging abilities. The problem however has been two-fold, lack of space for installation of hardware, and cost. Surprisingly sufficient advances have been made in both areas, and there now is little reason for any project not to take advantage of the higher control technology.

PRESENT DREDGE EQUIPMENT AND SYSTEMS

Today's state-of-the-art hydrographic survey and dredge positioning systems currently used by a number of major dredging companies, government agencies and other navigation-based commercial concerns offer high degrees of accuracy and reliability that exceed even the wildest dreams of the industry founders. The fact is that there have been so many hardware advances in the past five to seven years that it would not be possible to list them all within the context of this document, but the major components can be summarized as follows:

<u>Conventional DGPS</u> (Differentially corrected GPS) now can produce up to ten positions per second, with a reasonable expectation that most of the output will be within one or two feet of true position. In addition new firmware has improved multi-path rejection capability around large metallic structures such as bridges, making them even more reliable. Differential correction stations are more available than ever, and if a station is not within range, some systems come with built-in Omni-star ™ correction capability. Once

properly set up, these systems are extremely easy to operate, and are very reliable. The remaining weakness of conventional DGPS is its inability to generate reliable vertical elevations; however, this should not seem unreasonable, since its limit of horizontal accuracy (one to two feet) is well within most application needs for horizontal position. If the same tolerance were applied to a vertical component, however, it would render data that would be totally unusable by today's dredging standards. As a result most users seek other more efficient means of generating vertical elevations.

Real Time Kinematic GPS can produce one or more horizontal and vertical positions per second with accuracy in the range of one inch or less. These systems require a good deal more skill to set up, and correspondingly more purchase cost and technical support. Their application is intended for conditions where extreme accuracy of positioning is required. These systems require a remote reference station and a radio link that has limitations on the distance that the rover can be away from the base station. In addition the primary control coordinates for the base station must be known to a tolerance near First Order conditions, or else the system will not function properly. The vertical component of most systems is also highly accurate; however, this unit should not be used without some independent method of data verification, as there are times during satellite "swapping" that the vertical position may go out by as much as two feet for periods of as much as ten to twenty seconds.

Heave or Swell Compensation is a device placed on a vessel to attempt to digitally define its buoyant action in the water. All floating marine vessels are subject to heave, pitch and roll, or variations in draft and squat. These can be significant factors in positioning either a survey vessel, or a dredge. All floating dredges go through some degree shift of draft change with every cycle. As ladders are lifted in and out of the water, or as the cutter moves into or out of heavy bank, the draft and pitch of the hull can change dramatically. Similarly, clamshell dredges and floating backhoes all bob up and down as their buckets enter and leave the water. Heave compensators have a series of devices that sense movement and attempt through complex mathematical formulae to keep track of all the ups and downs and rolls etc. of a floating object. They perform this task with a reasonable degree of accuracy; however, they are susceptible to error if the frequency of the movements do not fall outside certain limits. Generally speaking, the slower the pitch (time increment) of the oscillation, the less accurate the device becomes. In addition, these sensors need constant monitoring and recalibration by competent technical personnel. Nonetheless such devices do a very good job of minimizing vessel oscillations, and they should be considered for any operation where digging depth is critical.

Electronic Tide Gauges (or water level gauges) have been an industry standard for many years. These are the least problematic devices presently on the market as long as one stays ahead of marine growth and battery changes. Most gauges will provide reliable real-time digital water level data of 0.1 feet or less, at variable time increments that can be set to meet project requirements. The problem is that they can only report the tidal condition at the place where they are located and they cannot define swell conditions. If a project is located near the ocean, or in a river, significant differences will occur over relatively short distances, depending on the configuration of the water body. One must be diligent to be sure that the water level conditions at the gauge match the conditions at the dredge. It is a historical fact that *the most common source of error in any survey or dredging project is the application of the tidal data*.

Echo Sounders have progressed significantly over the past ten years, with the most significant advancements being the introduction of better low frequency data collection and the multibeam full coverage mapping. While both of these features have yet to be integrated into one system, individually they have greatly enhanced the ability to collect accurate meaningful data, which is a fundamental requirement for a successful project. Basically, without good baseline data before, during and after dredging projects, control of the digging device becomes meaningless. Until the advent of swath technology (multibeam), surveys merely sampled data in rows spaced 25, 50 or 100 feet apart, leaving between 20 and 90% of a particular bottom area unmapped. While this might be a acceptable pre-dredge condition (presupposing that a soft bottom would be reasonably uniform), it is near fantasy to think that a single row of soundings five feet wide, and spaced 20 to 95 feet apart represents everything in between in a post dredge condition. Multibeam survey systems fixed this problem, at least in deep water. Further, since most contaminants bind themselves to the fine soft sediments, dual frequency mapping that has the capability to identify layers and hard bottoms becomes an invaluable tool not only in identifying and mapping sediment layers, but in imaging the thoroughness of the cleanup and materials left behind. The biggest problem yet to be solved is adapting this equipment to shallow water, where a significant amount of remediation must be done.

Software seems to do nothing but get better every year, enhancing not only mapping, but in providing dredge guidance, and tracking progress. The effectiveness of development has been largely the result of a few diligent companies that aggressively solicit feedback from the industry to help improve their products. Systems now have the ability to produce color contour maps for dredge operators to virtually "see" where and what they are digging in real time. It is worth noting however, that the present systems can only tell one where the cutterhead (or bucket) has been, they cannot as yet tell how effective the digging process was. To truly determine what a dredge has or has not excavated still requires progress surveying by conventional means. There have been some prototype plans to integrate a multibeam system into the bow of a dredge so that a digging area can be mapped as the dredge progresses. However before this can happen there are serious technical issues that need to be overcome in order for sounding equipment to "see" through the turbidity plume in the immediate area of the dredging. That said, this industry has overcome much larger challenges, so one can assume that it is only a matter of time before this capability is standard practice.

PROJECT CHALLENGES

During the course of our practice over the last twenty to twenty-five years we have encountered numerous challenges while providing dredge consulting services to both large and small dredging projects. As projects become more sophisticated, the assumption becomes that technology will have all the answers for the dredge contractor. Over the past ten years our firm has successfully worked with marine contractors and dredging companies to complete the following abbreviated list of increasingly more difficult projects, each one with more stringent accuracy requirements. This brief encapsulation demonstrates just how far dredging and positioning accuracy has advanced in a very short time:

- Boston Risers: The 1991 project involved dredging and the placement of 54 casings 230' in length for a diffuser located 9.5 miles offshore in the ocean in a depth of water exceeding 110'. The project was one of the last pre-GPS major marine projects to use microwave positioning for construction, in fact even though GPS was in its infancy, sophisticated quality control in the survey techniques used allowed a high degree of accuracy in recording as-built data. The required as-built position of the riser had to be reported to an accuracy of two feet.

- CA/T Third Harbor (Ted Williams) Tunnel: The 1994 project involved the then use of microwave positioning equipment to prepare pre, interim, and post excavation hydrographic surveys, including the monitoring of the post-installation placement of cover material, and the employment of the first "swath" survey technology to map the tunnel trench.

- CA/T Fort Point Channel: The 1997 project involved the adaptation of GPS RTK technology to a wire-supported inclinometer to project the precise location of a soil-mix operation auger, for a soil-mix operation, to a tolerance of three (3") inches from atop a 160-foot boom located on a floating barge.

- Boston Riser Venting Project: The 1998 project involved the placement of a casing 230' in length and weighing over 200 tons on a diffuser located 9.5 miles offshore in the ocean in a depth of water exceeding 110'. The project was complicated by the fact that the RTK-GPS system utilized for the project was at or beyond its stated operating limits. This time repeatable position accuracy was attained to within two inches at a small fraction of the cost and effort required seven years earlier. The operation also required 24-7 manning by a CLE engineer to ensure the proper operation of all dredge systems.

- NY Athletic Club: The 2000 project involved the adaptation of GPS technology and hydraulic dredge ladder inclinometer to locate, monitor and record the precise location of the dredge head while digging lead-shot within the dredge sediment strata. The operation also required operation of the system by CLE engineers on a 24-hour basis to ensure the proper operation of all dredge systems.

- New Bedford Harbor Superfund Site: The 2002 project involved the excavation of PCB contaminated sediments with concentrations exceeding 100,000 PPM. A number of techniques, equipment and resources were utilized to successfully complete this project.

- Hubline Project: The 2003 project involved the placement of a 33" natural gas pipeline in Boston Harbor from Beverly Harbor to Weymouth. The marine contractor was to provide GPS based dredge/barge positioning and to perform hydrographic surveys and provide 24-7 manning by a CLE engineer to ensure the proper operation of all dredge systems retained CLE.

ATTAINING THE NEEDED ACCURACY

In setting up instrumentation on a dredge to allow it to accurately perform its task of excavating a specific project there are several prerequisites that must be ascertained in advance. These include:

- What type of equipment will be used to dredge?
- What are the required digging tolerances?
- What are the space allowances on the dredge for setting up instrumentation?
- What will the working environment be like?
- What is the nature of the water body to be dredged?
- Will the instrumentation be technically supervised?
- What is the cost/ benefit of the dredging tolerance versus the cost of attaining that tolerance?

The following are examples of highly reliable positioning systems that would give consistent, repeatable position and depth positions of various dredging tools to the maximum degree reasonably attainable. These systems not only have fundamental instruments to give primary position data, but they also have redundant systems to check on the function and calibration of the primary systems. The redundancy is recommended for two reasons, the first is that is provides a built in system test on the condition of the calibration. The second is far more practical which is providing a built in alarm when the system malfunctions. This is necessary because the marine environment is extremely hostile to sensitive electronic equipment; the saltwater environment is even more hostile. Under these conditions instruments malfunction for many reasons, and there is a natural tendency of operating personnel to assume that if an electronic positioning system is generating data, that the data being produced is good. This is not always the case, in fact the more precise the equipment, the more often its calibration should be checked. However, the degree of oversight and redundancy on a particular application however can vary from project to project. As cited in the bullets above, one must also consider the cost/ benefit ratio of the desired accuracy. If disposal costs for dredged materials are low (i.e. $10 - $20 per yard) then far less accuracy is required that if the disposal cost were $300 to $500 per yard. The example cases cited herein will start with the absolute most precise and reliable positioning system and obviously the most costly, then will suggest what might be eliminated to obtain lesser results. The systems are also broken into hydraulic and mechanical. Hydraulic dredges are then broken into large and small (such as portable); mechanical is further broken into clamshell and backhoe. This first section will deal only with equipment; that is merely what is required to attain the measurements of bucket/ cutterhead position. Thereafter equally important environmental issues such as installation, operation, and maintenance will be discussed. These are two separate issues, because it is one task to create the method of measurement, but another thing altogether to make it function properly.

The system required to give the best precision for hydraulic dredging would consist of the following:

- An RTK-GPS positioning system for both horizontal and vertical control of the dredge hull.
- An Electronic Compass such as a Short-Baseline DGPS azimuth determination system.
- A Heave, Pitch, Roll (HPR) compensator to determine the movement of the dredge and act as a backup for the vertical elevation determination.

- A real time electronic tide gauge.
- An inclinometer on the dredge ladder to determine the digging angle and depth.
- A pressure transducer depth gauge located on the dredge ladder as a back up for the inclinometer.
- A computer and software for navigation and control.
- A reliable source of survey data for the dredge software to reference
- A trained and experienced system technician and operator.

When using a system such as this, (assuming that it is properly calibrated) one could expect the variations or "stacked inaccuracies" to be present, the sum of which become the net real accuracy. The system described below should produce reliable horizontal and vertical cutterhead positions in the range of under three inches. This system is based on a large dredge; the system for a small dredge would not be much different, however the accuracy would be in the range of one to two inches:

- The RTK-GPS system would realistically produce position accuracies in the x,y and z ordinates of under one inch.
- An Electronic Compass such as a Short-Baseline DGPS Azimuth System is routinely accurate to 0.5 degrees or less, thus the distance from the compass or antenna to the cutterhead becomes critical to accuracy. For instance if the antenna is mounted on the pilot house and the distance from the antenna to the end of the cutterhead is 50 feet, then an additional horizontal inaccuracy of five inches is added.
- An inclinometer can have accuracy ranges from nil to one degree, so the quality of the instrument becomes a critical issue. If one assumes that the instrument is of reasonably good quality an accuracy of 0.2 degrees is a reasonable expectation, this would translate to about 1 ½" on a 40 foot ladder that would be added to the vertical inaccuracies.
- The heave-pitch-roll compensator (HPR), tracks fore and aft pitch and yawl of the dredge as it raises and lowers the ladder, and roll when bank conditions change (this affects the trim attitude of the dredge with respect to the position of the ladder). In addition local variations from tidal or stage stations occur regularly in rivers that need to be accounted for. The accuracy of the HPR sensor is realistically one to two inches depending on the duration of the HPR cycle, (i.e. the slower the movement, the less accurate the readings become which in turn produces a creep in the base position), thus the more frequent the calibration requirements become. This device also serves as an alarm for the vertical component of the RTK-GPS elevation. When satellite conditions deteriorate, the vertical accuracy of the RTK-GPS does also. When satellite conditions change for the better, they usually do so quickly, which results in a sudden jump or drop in elevation. If this jump is not matched by an equal jump in the heave compensator, there is an alarm, thus letting someone know that there is a problem.
- A water depth gauge would be installed on the ladder, at some point far enough from the cutterhead to avoid damage. This device serves as a backup for the inclinometer, and is also used as a QA check on the system calibration. When the ladder depth calculated using the slope indicator falls out of synchronization with the depth calculated by the depth gauge, there is an alarm, thus letting someone know that there is a problem.
- The Computer and Software systems receive all of the input from these devices, sort it out, and present the data in a graphic image to both the system operator, and the dredge operator. It should be noted that all of the cabling required for the computer and its input channels (cabling) is one of the biggest sources of system problems. The computer must be rugged, and placed in a location where it will not be fried by the sun or soaked by rain or spray. Cables must be properly located and connected with proper devices to assure solid weather tight contact.
- Quality baseline and progress survey data is necessary for background of the dredge operator's screen. Unlike channel dredging projects that are normally dredged to specific depths and templates, a remediation could involve removal of a few feet of bottom sediment, using the existing contours as a base point. Likewise there could be specified areas at various differing depths coordinated to match contaminated soils found in borings at varying depths.
- The System Technician and/ or Operator must be an individual trained and proficient in the installation, programming, use and maintenance of the positioning systems. All of the technology discussed heretofore is in reality, no better than the person managing it. The simple fact is that all

of the above instrumentation requires calibration and coordination, and if any one component is not properly set up and maintained then the resultant position data will not be accurate. The time honored axiom "garbage in = garbage out" is more of a truism in maritime instrumentation systems than anywhere else, because the potential inaccuracies are rarely apparent until it's too late. Whether the data that a system generates is accurate or bogus, the inexperienced eye routinely has a difficult differentiating the two. The system operator must constantly be on guard, regularly checking and rechecking the system and the redundant backups, this is the only way consistent, accurate data will be produced. He or she must be able to resolve issues quickly and assure that all components are calibrated and functioning properly. The challenges can range from the simple "creep" on instrument settings (common in HPR systems), simple corrosion in an electronic connection, the corruption of an almanac database or the malfunction of one of the system components. If one of the above occurs, the system does not always shut down, it merely shows inaccurate data, which the inexperienced eye all too commonly misses. All too many system technicians/ operators have obtained at best on-the-job training, with little or no formal training in sophisticated instrumentation systems. Ideally the certification of an "operator" by a sanctioned training program would provide greater stability and redundancy to the entire positioning process.

A system designed for a clamshell bucket dredge would employ most of the same instrumentation cited above with the following exceptions:

- A digital cable payout and retraction indicator, would be used in lieu of the inclinometer. This device digitally determines how much the cable holding the bucket is paid in or out, thus raising or lowering the bucket. This would be the primary device to determine bucket depth, primarily because it would be out of the water and less susceptible to corrosion or damage, thus would be more reliable than a depth indicator on the bucket. It is assumed that the bucket would be an environmental design such as Cable Arm ™ and that the bucket would be raised and lowered with a reasonable degree of care so as not to create excessive slack or jumping of the cable.

- A water depth gauge could be installed on the bucket, as a redundant check on depth, but unless the operators exercise a reasonable degree of care they are easily damaged. Optionally, this device could be installed for calibration, and then removed when not in use.

- All other instrumentation, equipment and personnel would remain the same.

A system designed for a backhoe dredge would employ much of the same instrumentation with the following exceptions:

- A series of digital 360^{o} inclinometers would be mounted on the various segments of the backhoe dipper in lieu of the inclinometer or payout indicator. This would be the primary device to determine bucket depth and angle, and they are thus coordinated within in the software. The weak link of this system is the indicator for the bucket, however an articulated extension device is normally used to move the indicator up to the dipper arm.

- A water depth gauge could be installed on the dipper, as a redundant check on depth, but unless the operators exercise a reasonable degree of care they are easily damaged. Optionally, this device could be installed for calibration, and then removed when not in use.

- There are one or two of these systems manufactured as packages that have proven reasonably reliable with ten plus year track records.

SETUP and OPERATION

Owning and operating a sophisticated electronic positioning system is a lot like owning a boat. That is to say, the initial purchase price is only a percentage of the work and cost of ownership. However, properly set-up operated and maintained, a good system can give a significant return on investment. Conversely, if they are installed or operated by inexperienced personnel, or installed without a reasonable degree of care, they can become the proverbial "hole in the water", and will yield poor results.

Set up:

One has to remember that a dredge is normally a very hostile environment for sensitive electronics, and this has to be kept in mind while installing the system. Following these installation rules make a big difference in the end use reliability:

Computer: Unless the dredge is equipped with a reasonably secure, dry pilothouse the computer should be housed in a weatherproof high-strength plastic box. It should be kept out of the way (as under a counter), away from windows and off of the floor by at least a few inches. Install water resistant pigtails for the connections through the wall of the box and seal the openings to prevent water entry.

Wiring: All wiring and cabling should be routed in out of the way locations where they won't be walked on, tripped over, crushed and the like. Where possible they should be kept together on the same route (except those needing to be isolated). Permanent installations should be installed in conduits; temporary installations should have the cables wrapped together with several layers of duct-tape. Outdoor connections should be kept to a minimum, making metallic soldered watertight connections where necessary (90% of all system problems emanate from corroded outdoor connections). Connections should be located where they can be accessed for inspection. Inside, quality connectors or terminal blocks should be used, again taping them with several thicknesses of duct or electrical tape.

Instruments: All instruments should be mounted on strong welded steel mounts, with protective shrouds if possible. Devices installed on ladders or booms need very strong protective covers and steel conduit, even then they will be damaged or lost occasionally. Common sense and experience go a long way when locating instruments with respect to damage exposure.

GPS Antennas: Antennas need to be located away from sources of multipath. Even though the newest systems have excellent anti-falsing firmware, why introduce a possible source of error if it isn't necessary. Here again, locating the antenna where it is less likely to be damaged is also prudent, if it must be mounted at the top of a boom, make sure it won't be hit by some moving part.

Offsets: All offsets need to be verified by field measurement; for complicated offsets, such as positioning the inclinometer on a dredge ladder, layout plans for the dredge should be obtained, then the motion should be checked in a CAD model to verify the operation logic. This is a very critical step in making sure that instrument readings accurately emulate the actual digging device.

Operation:

All systems need to be calibrated by experienced personnel. All of the instrument accuracy in the world is useless if it isn't calibrated properly. This not only applies to the initial setup calibration, but it means rechecking on a regular basis. The degree of accuracy of a system is directly proportional to the regularity of the system checking and oversight. As the requirement for accuracy becomes more stringent the need for competent oversight goes up. The extremes of required oversight can vary widely; for instance a simple DGPS that produces sub-meter horizontal positions only needs to be checked once a week or less (usually the operator will notify someone if they feel a checkup is needed more often). At the opposite end of the scale, an RTK-GPS system with integrated vertical controls that needs the maximum accuracy possible generally requires full time oversight. If cutterhead or bucket positions are being tracked and logged by the computer a second technician may be needed. Generally speaking the quality of logged data is three to four times more usable when an experienced technician monitors it. Backhoe and clamshell vertical measurement devices vary but generally need calibration once each day; however, the frequency of each system needs to be evaluated independently. In addition the more sophisticated systems need more regular maintenance, than the simpler systems. Properly maintained systems will be very reliable, un-maintained or poorly maintained systems break down often and thus yield far less consistent results.

Field Tests:

Once one has determined the best instrumentation to use for a particular task, and properly installed it, then properly calibrated the system, all is in order to produce an accurate picture of the position of the bucket or cutter. However, this picture may not relate directly to the actual finished dredging product unless the system is tested and checked. Thus the last critical step is field-testing the properly calibrated dredge and instruments against what its actual digging patterns. To accomplish this, the dredge needs to dig a test area or possibly a few test areas, carefully logging the digging data in each area. Thereafter the test areas must be carefully and thoroughly surveyed, then the results of the surveys compared to the logged data. From this process experienced personnel can develop a true relationship between the digital data that has been obtained from the instrumentation and the actual finished product that the dredge produces. Once this final step is completed everything has been done to reasonably assure the dredge is digging as accurately as possible, and the balance is left to the dredging plan and skill of the operator.

Quality Control:

At the end of the day, when an area has been dredged the final step is to check the overall quality of the work. This requires surveying the area dredged then identifying areas needing additional work. This may seem like an unnecessary step given all of the foregoing effort that would have been taken to assure the quality of the dredging. It should be noted however, that if all of the above steps were followed, assuming a realistic production plan, favorable working conditions and reasonably skilled operators that excellent results should be attained. However no matter how careful an operation is there is no known system that will work with 100% efficiency, thus the final step of surveying is still the best final quality control step to assure the work is completed properly.

On this issue, and looking ahead to more efficient ways of quality control surveying we have been asked many times if there is a way to integrate a hull mounted survey system into the dredge. Actually there have been a few projects where large dredges used a surveying sweep system mounted to a device near the bow of the dredge. This did not save any large amounts of labor, because a full time engineer was still required to operate the system; in fact it slowed the dredging operation because the work had to be stopped to allow turbidity to settle so that the survey could proceed. However, there were advantages, because it allowed the contractor to sound directly under the dredge before moving out of an area, and thus saved some movement of the dredge.

Summary & Recommendations:

As dredge positioning systems become more sophisticated in the ensuing years, the needs and expectations from the owners and dredgers will increase at a rate ahead of technology. That is to say that there will always be a growing need for more information, more accuracy and more reliability. True to form, the technology will always be there on paper; attaining the performance in the field will be another matter. The one constant will be the ability of an individual, (a technician, a system operator) to provide the connection to reality, which we call Quality Control. Inherent in this discussion are the most simple of basic concepts that have been quested since the time of the Egyptians:

1. Do we know where we are?
2. Do we know where to dig?
3. Do we know if we are digging deep and wide enough?
4. Do we know when and where to stop digging?

The benefits to the industry will be a standardization of expectations from positioning systems and Quality Control methods that will result in an improvement in the results of the dredging projects that they are applied to.