DREDGE GUIDANCE TECHNOLOGIES - ENVIRONMENTAL DREDGING PROJECTS: TWO CASE STUDIES

John A. DeRugeris[1] and Susan E. Nilson[2]

ABSTRACT

Dredge guidance technologies are currently being used for a number of different applications to improve dredging accuracy within tight tolerances in contaminated areas. In these areas, costs of additional excavation or conversely of not removing the entire specified area are significant. The following paper presents two case studies in which dredge guidance technologies were effectively used to monitor the removal of contaminated sediments thereby limiting the overall cost of the projects.

Case One: Lake Capri, West Islip, NY

The subject project involved dredging of contaminated sediment from a 16-acre lake on Central Long Island. The objective of the project was to thoroughly remove the upper layer of sediment while leaving the underlying uncontaminated sand layer relatively undisturbed. To accomplish this, the New York State Department of Environmental Protection specified that a precision GPS system be used to track the dredging progress and an electronic depth gauge be utilized to verify digging depths. CLE was assigned the task of implementing this plan and used several unique methods to meet the owner's needs.

To establish the required dredging envelope a standard hydrographic survey was conducted to determine the top of the elevation of the original sediment. An extensive probing program to obtain the elevations and determine the uniformity of the harder underlying sand layer followed this survey. The data was then compiled into a "finished grade" contour plan in electronic format that would be used to guide the dredge operator. Digging depths varied from three to five feet and changes in grade were gentle. The dredge was outfitted with a sub-meter real time positioning system and an electronic depth sensor as well as mass/density and flow monitoring of the dredge discharge. The operator could view the screen and determine the required digging depth in the particular work area in 0.25-foot increments (digging tolerances were plus 0 inches and minus 6 inches). The operator also logged data from each pass of the dredge to provide data for the development of a plan for reporting quality control monitoring of the coverage. Final surveys were conducted with a dual frequency fathometer to allow monitoring of the residual loose sediments, and allow creation of additional dredging overlays in areas that needed re-dredging.

Case Two: Lower Harbor, Pelham, NY

A small harbor located on Long Island Sound, the subject project involved removal of a ten-inch layer of contaminated sediment. The restoration plan called for close monitoring of the dredging work to assure that the dredge covered all of the contaminated area, and dredging depths held to close tolerances. As with Case One, the restoration plan called for electronic positioning and logging of the area covered by the dredge as well as a visual display and logging of the dredge cutter head depth. This project went a step further than its predecessor by requiring that a technician is on board the dredge at all times to monitor the dredging depth and coverage as well as operation of the data loggers.

Because bottom depths varied from zero to ten feet it was necessary to first perform a detailed hydrographic survey of the work area, then to convert the results to a half-foot contour plan. The plan was then converted to an electronic display to give the dredge operator a real time picture of the required finished dredging depths. Combining the electronic depth display with an electronic tide gauge compensated for the seven foot tidal cycle. This data was utilized to set the cutter head to the required digging depths shown on the display. At the conclusion of the project the predredge survey was overlaid on the digital dredging log in section view to determine if the coverage and depth removal criteria had been met.
Keywords: GPS, contaminated, cutterhead, position, real-time monitoring

[1]John A. DeRugeris, P.E., President, CLE Engineering, Inc., 15 Creek Road, Marion, MA 02738, (508) 748-0937, (508) 748-1363 Fax, JCOASTLINE@aol.com
[2] Susan E. Nilson, P.E., Project Manager, CLE Engineering, Inc., 15 Creek Road, Marion, MA 02738, (508) 748-0937, (508) 748-1363 Fax, SNILSON@CLEengineering.com

INTRODUCTION

Dredge guidance technologies are currently being used for a number of different applications to improve dredging accuracy to closer tolerances in contaminated areas. On such projects, costs of over-excavation or conversely of not removing the entire specified quantity may be significant. The following paper presents two case studies in which dredge guidance technologies were effectively used to monitor the removal of contaminated sediments thereby limiting the overall cost of the projects.

CASE ONE: LAKE CAPRI, WEST ISLIP, NY

Lake Capri is a 16-acre freshwater lake located in Central Long Island. It is fed by a small stream and empties via a spillway into a tributary of the Southern Long Island Intercoastal Waterway. The pond was originally about five feet deep with a sand and gravel bottom. Because of its configuration, which is much like a settling basin, it filled with organic sediment over the past several decades. At the time of the inception of this project its net depth below the spillway elevation ranged from zero to two feet. When it was learned that the sediment was contaminated with plating wastes, the State of New York took over the restoration project. The objective of the project was to thoroughly remove the upper layer of contaminated sediment while leaving the underlying uncontaminated sand layer relatively undisturbed. To accomplish this the consultant for the New York Department of Environmental Protection specified that a precision GPS system be used to track the dredging progress and that an electronic depth gauge be utilized to verify digging depths. CLE was assigned the task of implementing this plan and used several unique methods to meet the owner's needs.

To establish the required dredging envelope a standard hydrographic survey was conducted to determine the top of the elevation of the original sediment. This survey was followed by an extensive probing program to obtain the elevations and determine the uniformity of the harder underlying sand layer. The data was then compiled into a "finished grade" contour plan in electronic format that would later be used to guide the dredge operator. Target dredging depths varied from three to five feet with gentle changes in grade.

The dredging contractor, Mobile Dredging & Pumping Company, utilized an Ellicott "Mud Cat" dredge. This particular equipment is a hydraulic dredge and utilizes a taught cable as a means of stationing and moving itself through the dredging area. The dredge digs by moving itself forward in a series of parallel lines, each successive pass slightly overlapping the previous one. The width of the "Rototiller" type cutter head of the Mudcat is eight feet, thus to obtain total bottom coverage and compensate for inherent inaccuracies in the process a somewhat lesser line offset is required. During the dredging process the forward movement of the dredge works much like a bulldozer or front-end-loader, forcing the sediment into the auger casing while the auger rotates placing the silt into suspension in the water column, then allowing the mixture to become fluid, where after it is pumped to its destination. Because of the relative wide width of this "swath" and the small size of the pump, the forward progress of this equipment is much slower than the conventional cutter head dredge, making control of the cutter depth easier for the operator to control, thus a very level plane is not difficult to attain. Forward velocity does, however become very important; for if the velocity is too fast, the cutter box becomes overloaded and the semi-suspended sediment is "bulldozed" to either side, falling behind the auger box, thus leaving shoals. The inherent problems attaining total coverage with this type of dredge were aggressive forward movement (as described above) and wind creating a centenary in the cable and pulling the dredge off line laterally beyond the designated line overlap offset.

The total dredge-monitoring package consisted of a 20 centimeter differential GPS positioning system, a 0.1-foot accuracy electronic depth sensing gauge, a navigation computer with logging capability, mass/density and flow monitoring of the dredge discharge, and a turbidity monitoring system. The components of the system were as follows:

1. To position the dredge to the specified tolerances a Trimble sub-meter differential GPS system was installed on the dredge. The antenna was placed on the forward most part of the hull, toward the center, and corrected within the software program to provide the operator with the position of the center of the cutter head. The accuracy of the positioning system was 20 cm (about 8 inches) for 95% of the positions shown on the screen. Positions were transmitted to the computer and updated on the monitor at one second intervals.

2. Depths were also recorded at one second intervals using an electronic depth sensing device placed near the cutter head. This device had the capability to accept corrections for local conditions (water temperature, etc.) and offsets to provide a true reading of the dredge cutter depth. This device employed a digital readout display accurate to within one tenth of a foot, and was placed in the dredge cab where the operator could view it. This device proved far more accurate than the conventional ladder gauge installed on the dredge.
3. The operator could view the computer's on screen display and determine the required digging depth in the various work areas. Depths were identified by contours at 0.25 foot increments; required digging tolerances were plus 0 inches and minus 6 inches. The operator also logged the position information from each pass of the dredge to provide data for the development of a plan for reporting quality control monitoring of the coverage.
4. To determine the effectiveness of the dredging several quality control hydrographic surveys were performed. These surveys were conducted by conventional means: using a dual frequency fathometer to allow monitoring of the residual loose sediments. To accomplish the level of detail required, sounding lines were run in two directions at relatively close spacing, and digital models were run of both frequencies. More detailed information of the finished work would have been desirable, but due to the shallow water depths and the dual frequency requirement, multi-beam surveys would not have been practical.

After analysis of each survey, dredge operations were modified as required in order to best accomplish sediment removal. To achieve nearly complete sediment removal from the lake bottom, the dredge had to make several independent passes over the dredge area. The first series of passes removed 90% of the sediment, but left random "wind-rows" of undredged sediment as well as several inches of partially suspended sediment. During the initial dredging phase it was learned that reducing the forward speed of the dredge and making the cuts in "lifts" rather than one or two passes reduced the "bulldozing" characteristics as well as the residual sediment. The "wind-rows" were removed during the phase two dredging which was a complete re-dredging of the entire area. The suspended and partially suspended sediments proved more elusive by their very nature. It was discovered during the phase two re-dredging that the polymers being returned to the lake from the dewatering operation were acting as a flocculent and consolidating both the residual sediments as well as the new sediments entering the pond from rainfall runoff. This semi-consolidated material collected in several areas of the lake during the phase two operations and required almost a complete third dredging to achieve satisfactory removal. Upon completion of the third dredging only a six inch layer of suspended sediments (the consistency of dirty water) remained. It is the opinion of the author that removal of this material would have been virtually impossible. Samples of this material showed no evidence of residual contaminant.

Final Project Analysis: Positioning System:

The positioning system utilized for this project proved to be very satisfactory from the perspective of reliability and control of dredging operations:

1. It reliably provided the operator with a real-time picture of the project, and allowed tracking of the dredge progress and areas covered.
2. In conjunction with the electronic depth gauge, the real-time on-screen display allowed the operator adequate control of digging depths.
3. It was anticipated that the dredge operator would be able to utilize the computer's logging function to keep track of the dredge's physical progress. This turned out to be impractical, as the operator had to focus his attention on dredge operations, and maintaining grade. Adding the task of computer operation proved to be more than one person could effectively handle without reducing the quality of the finished product. As a result, data logged by the operator was not consistent, and therefore of marginal value compared to the quality of conventional survey data.
4. While in theory the computer data log of the dredging operation may have been an effective method of quantity and quality control monitoring, thus eliminating the need for progress surveys, this proved unreliable and not cost effective in practice.

5. Follow-up, detailed progress surveys proved to be a necessary and valuable tool for assessing the effectiveness of the dredging program, as well as being the most cost effective quality control method. Surveys were supplemented with a program of grab-sampling and testing.
6. All of the control measures outlined above proved necessary to accomplish the clean-up criteria established for the project.

Overall Analysis of the Project:

Reviewing the success of the project as a whole, the following observations were made:

1. Real-time Computer/GPS dredge guidance systems are a necessary and valuable tool for control of environmental remediation projects.
2. The use of the on-screen control display, and electronic depth measuring equipment proved to be very effective tools to allow the dredge operator to maintain reasonably accurate grade control.
3. The guidance computer can be used to log data, and keep track of dredging coverage and progress; however, in order for this function to be effective someone experienced in computers and preferably also in hydrographics should operate the system. It should also be noted that to generate data for more than general use takes a considerable amount of reduction time, and while very useful in the day to day operation and planning it cannot realistically substitute for the conventional hydrographic surveys.
4. The "Mud Cat" dredge was a very effective tool for removing the sediment in a systematic pattern due mainly to the configuration of the cutter head. Controlling the forward speed of the dredge and removal of the sediment in 10 inch to 14 inch lifts also proved to be important factors in minimizing the amount of residual sediment.
5. In order to obtain reasonably complete sediment removal, the area to be dredged must be covered more than one time. The number of repeated coverages will vary according to the nature of the sediments and the skill of the dredge crew. If a Mud-Cat dredge is utilized, subsequent re-dredging passes should be run at 90-degree angles to the preceding series.
6. If polymers are used as part of the dewatering process, consideration must be given to the location of their return to the dredge area. If the flow characteristics of the waterway are such that the unconfined effluent travels through a completed dredge area, one can expect that they will cause residual sediments to reaccumulate very quickly in those areas.

CASE TWO: LOWER HARBOR, PELHAM, NY

The subject project included the removal of a ten-inch layer of lead shot contaminated sediment from a small harbor located on Long Island Sound. The restoration plan called for close monitoring of the dredging work to ensure that the dredge covered all of the contaminated area, and dredging depths held to close tolerances. As with Case One, the restoration plan called for electronic positioning and logging of the area covered by the dredge as well as a visual display and logging of the dredge cutter head depth. This project went a step further than its predecessor by requiring that a technician be on board the dredge at all times to monitor the dredging depth and coverage as well as operation of the data loggers.

Lower Harbor, near Pelham, New York had been the location of a sport trap shooting facility for nearly fifty years. This facility was configured with trap houses located on the banks that ejected clay target pigeons over the water, and were in turn fired at by members using shotguns discharging lead pellets. The landing zone for both the shot and lead pellets were principally confined to three areas ranging in depth from zero to ten feet (mean low water). Surface soils in the waterway were organic silt and samples showed that the shot and clay fragments were principally confined to the upper ten inches of sediment. The restoration plan called for this upper ten inches of sediment to be dredged, the shot removed, then the washed sediment returned to harbor bottom.

The sediment "washing" operation was performed in the following manor. First, the hydraulic cutter head dredge removed the sediment. Attached to the dredge was a small barge with a separator that functioned much as a sand wash. The equipment was sized so as to filter out the broken clay targets and keep the sediment and sand in suspension for overboard discharge, while allowing the heavier lead to settle out into a collection bin. The lead and clay were manually removed from the screening and settling operation on a daily basis, then drummed and sent to a recycling facility. The dredging contractor, Mobile Dredging & Pumping Company, utilized an eight-inch cutter head dredge to perform the work.

The technical monitoring portion of the work required that the dredge be positioned with a real-time electronic positioning system with sub-meter accuracy, and that the cutter depth be located to an accuracy of one half foot. The system furnished by CLE far exceeded this requirement: a DGPS system with 20 cm accuracy was used for raw positioning. The azimuth of the dredge and antenna offsets were compensated for with a fluxgate compass, and depths were obtained by use of an electronic depth sensor located near the cutter head. The six to eight foot tides were logged with a Hazen Electronic tide gauge. An on-board computer using Hypack for Windows software collected the data and provided a real time on-screen display for the dredge operator, and provided a platform for logging data.

Because bottom depths varied from zero to ten feet, it was necessary to first perform a detailed hydrographic survey of the work area, then to convert the results to a half-foot contour plan. The plan was then converted to an electronic display to give the dredge operator a real time picture of the required finished dredging depths. Combining the electronic depth display with an electronic tide gauge compensated for the six to eight foot tidal cycle. This data was utilized to set the cutterhead to the required digging depths shown on the display. In some areas of the project, bottom depths changed radically from one side of the dredge swing to the other. In these cases it was impossible for the dredge operator to use the computer as the sole source to determine effective cutting depth. This part of the work required considerable skill on the part of the operator to balance the readings of the pressure gauges with the depth and position data, and to literally “feel” his way through the swing, changing ladder depth as the dredge moved.

Because the dredge cutter head was rounded, it was impossible to grade the finished cut to a “flat” bottom as with the Mud-Cat type dredge in Case One. Instead, the dredge left the bottom with a classic series of arc shaped troughs looking much like a freshly plowed field. This meant that in order to meet the specification requirement of a minimum of ten inches of sediment removal, the dredge had to over-dig by a predetermined amount to retain a certain amount of overlap to assure a minimum of ten inches of sediment removal. Since sediments react differently to dredging depending on their size fraction and density, a series of test passes were conducted in shallow water where the results could be easily observed. The most effective pattern of cutter depth versus dredge step length was quickly established, and the dredge was then able to proceed with the work.

Properly logging the data from the project also proved to be challenging. Unlike Case One where the dredge advanced in straight lines at six foot offsets, this dredge made several swings in the same location to reach final grade, then stepped ahead approximately two feet to repeat the process. Left unchecked, this process would generate an inordinate volume of data, which in turn required considerable post process editing. The development of optimum method for data logging took several days of trial and error and ultimately required the re-dredging of some small areas before the best method was determined.

Essentially three methods of logging data were tested, and ultimately one utilized; however, none were considered optimum without some form of drawback. The pros and cons of each method are as follows:

1. The first method was to log all data; i.e. starting the data logging and leaving it run for a fixed period of time, logging all production and some non-production time. This method required the least attention of the technician, and provided redundancy in case of data loss; however, the volumes of data generated were enormous, and virtually impossible to segregate and accurately edit.
2. The next method tried was involved only logging the last pass of each swing of the dredge. This data was considerably easier to edit; however, there was no redundancy, and propensity for data loss through some inadvertent error proved to be prevalent. That is, if for any reason, the technician was preoccupied, or a keyboard malfunctioned, or any of a number of other events occurred when the operator was making the last pass before stepping ahead with the dredge, this data was not logged. This condition did not normally show up on the monitor, and thus would go unnoticed until the dredge

would shut down and the technician would have time to review the logged data. As a result there were "holes" in the dredge record where no data was recorded and thus the missed areas would have to be redredged.

3. The method finally utilized was the least prone to problems, rather than the best solution. Under this scenario the technician logged all data for a fixed series of steps of the dredge. Further if the dredge stopped for more than a few minutes, the data logging was ended and restarted when the dredge resumed operation. This method provided redundancy in the collected data, and was far less prone to data loss; however, it still generated formidable volumes of data, most of which had to be manually edited for the final dredge analysis. It required approximately three hours of post processing for each hour of dredge operation.

Overall Analysis of the Project:

In the final analysis, the method used for dredge monitoring proved to be an effective and valuable tool for gauging dredge progress during an environmental restoration project. The logging of data, although tedious, was also an effective tool for monitoring and quality control. However, while area coverage data was typically readily available on the dredge, correlation of depth data took considerably more time because of the extensive editing required. Also as in Case One, monitoring of dredge data should not be substituted for progress and/ or final conventional hydrographic surveys, nor is attempting the same cost effective. Further, the use of dual frequency sounding equipment in progress and final surveys, coupled with a soft sediment coring program will yield far more cost effective and reliable results.

CONCLUSIONS

GPS technology is a necessary and viable tool for both control and monitoring of critical dredging projects. The quality of positioning equipment and software has advanced dramatically in recent years and it is reasonable to expect further advances in systems producing higher quality work at an ultimately lower cost. Commercially available positioning equipment and software have proved sufficiently accurate and more cost effective than custom systems. These systems can effectively be used to produce digital dredge monitoring logs.

Digital dredge monitoring logs are best used in conjunction with corresponding hydrographic survey data. Therefore, the importance of obtaining thorough and accurate information of existing topography and conditions should not be overlooked. On board monitoring can not replace independent monitoring such as hydrographic QC surveys. In addition, development of daily quality control mapping requires professional data reduction; it is a common misconception that unedited data can be used as the finished product. Once validated, edited data can be used in conjunction with hydrographic survey data to dramatically improve effectiveness of dredging as well as reduction of over and under dredging.

Designers need to know the capabilities and limitations of available equipment and software. Specifying realistic goals for data acquisition that are consistent with specified project quality control requirements, along with a properly administered program, will improve the quality of the final completed project. Monitoring by trained professionals on board can effectively improve the work product and reduce dredging time and overall project cost.