Dredging Research Technical Notes

Testing and Evaluating the DRP Automated Load Monitoring System (ALMS)

Purpose

This technical note summarizes the final testing and evaluation of a hopper dredge Automated Load Monitoring System (ALMS) developed under the Dredging Research Program (DRP). This research effort was conducted under the DRP work unit "Technology for Monitoring and Increasing Dredge Payloads in Fine-Grained Sediments."

Background

Current methods of dredge load monitoring by government and industry are labor intensive and subject to significant error. Typically, for coarse-grained sediments such as sand or gravel, hopper bin soundings are taken after the hopper is filled to gauge the depth of material in the hopper. To get a representative sampling of the sediment surface in the hopper, four to six locations are sounded. By referencing this average depth of sediment to the dredge hopper ullage table, the volume of material can be determined. This volume is then represented as the in situ production, assuming that the density of the material in the hopper is the same as that on the bottom of the project area.

Two major problems are associated with using the current method. The assumption that this material has the same density as that on the bottom of the navigation channel may be incorrect. The pumping of material into a hopper may "fluff" the material, temporarily increasing the unit volume of the material. The piping system used to place the slurry in the hopper may tend to concentrate or mound the material in certain parts of the hopper, thus skewing the measured sediment elevations in the hopper and increasing the potential for error in the production calculation. For lighter loads, the error introduced into the production calculation may be significant.

For fine-grained materials, the bin measure method is used. This method uses the change in displacement, typically determined by a chart recorder, along with the hopper volume to make the production calculation. This method will adequately calculate the in-place production in the hopper, as long as the bin water in the hopper before the load is accounted for.

A disadvantage of using this method is the difficulty associated with determining the bin water level. To make an adequate determination, the level of bin water in the hopper before each load must be determined either through visual inspection or by pumping the hopper out to a known volume before beginning a new load. Both of these methods are labor intensive and reduce the efficiency of dredging. Without adequate bin water volume determination, significant error is introduced into the production calculation.

The goal of the research conducted under this hopper monitoring technology work unit is to develop an accurate bin measure system that is capable of automatically measuring all dredge processes that contribute to the production calculation. The system must account for changes in bin water levels, potential hopper volume changes due to adjustable weirs, and dredge displacement changes and must automatically produce a production report as each load is finished.

Additional Information

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Introduction

The information presented in this technical note describes the development, testing, and evaluation of an automated load monitoring system. The system was designed through an evolutionary process of testing and evaluation.

The initial test of production monitoring instrumentation was conducted under the DRP during summer 1991 on the hopper dredge *Wheeler*. Acoustic sensors were installed and tested for real-time hopper volume measurement (Scott 1992). The acoustic sensors provided reliable and accurate measurement of hopper bin water volume and total hopper volume. The acoustic sensors were also used to measure dredge draft, but the data tended to be noisy because of wave action.

The accurate measurement of dredge draft/displacement is crucial to the bin measure process. Dredge draft and displacement are currently measured and displayed on a chart recorder on most dredges. The chart recorder operates through a change in hydrostatic pressure as the dredge drafts under load. The change in air pressure is transferred through bubbler air lines running from the keel to the pilot house. Reimbursable work with the U.S. Army Engineer District, Norfolk, provided U.S. Army Engineer Waterways Experiment Station (WES) engineers with the opportunity to investigate alternative methods for measuring dredge draft. WES engineers placed pressure transducers in the bubbler air lines of a contractor dredge to provide a record of dredge draft/displacement independent of the load chart. This test verified that the data from pressure sensors placed in the bubbler air lines were accurate and reliable.

Through the DRP and reimbursable work with the Corps district offices, the two instrumentation systems critical to the bin measure process (acoustic and pressure sensors) were tested and evaluated. Two other dredge processes were integrated into the automated bin measure design to provide signals to the computer for indicating when a load begins and ends. These processes are signal outputs from the density gauge and hopper door relays. The complete ALMS was installed on the hopper dredge *Wheeler* during the week of August 16, 1993, during operations at Matagorda Bay, Texas.

Instrumentation

Acoustic Sensors

The acoustic water level sensors used for the ALMS test were of the same design as those for the initial testing, during summer 1991. The sensors are designed for an operating range of 0 to approximately 21 m, with temperature compensation. The sensors have 29 programmable functions for defining the operation, based on environmental conditions and desired sensing ranges. The ceramic transducer element in the sensor is designed to resist the corrosive environment of dredge hoppers. For the *Wheeler* application, the sensing range was from about 0.5 to 14 m. The sensor was calibrated for a 4- to 20-mA output signal.

During the initial tests of the acoustic transducers in 1991, four transducers were installed over the *Wheeler* hopper. Only two were installed for the Matagorda Bay tests — one over each side of the hopper. The data from the acoustic sensors were averaged and processed through an ullage table calibration curve fit that relates depth in the hopper to hopper volume.

Pressure Transducers

Pressure transducers were installed in the bubbler air lines just before the lines entered the chart recorder. The *Wheeler* typically drafts between 3 and 3.4 m in salt water, which converts to approximately 35 kPa. The air pressure in the bubbler tubes was measured to be approximately 41 kPa. A 172-kPa pressure transducer was installed in both the fore and aft bubbler lines. The two draft measurements were averaged and used to determine displacement from a draft/displacement calibration table for the *Wheeler.*

Density Gauge and Hopper Door Relay Output

Additional output from other dredge processes was necessary to automate the load monitoring process. The combined outputs from the density gauge measuring slurry density in each drag arm and from the hopper door relays were used to signal the computer when a load was about to start. If the hopper door relays were closed (hopper doors closed) and the slurry density became greater than 1.05 g/cm^3, the computer initialized a load start condition and recorded initial conditions. When the doors opened, the computer initialized a load end condition and recorded final conditions.

Computer and Data Acquisition

A 386 personal computer was used to run the ALMS programs and acquire the data. The data acquisition board was programmed to receive the signals from the four instrumented systems. The load analysis program calculated production from the data recorded for the initial and final load conditions and produced a real-time production report as each load cycle was completed. The computer prompted the user for initial project conditions such as water density and in situ sediment density. An uninterruptable power supply provided power to the ALMS.

ALMS Operation

A flowchart of the steps describing the ALMS operation is presented as Figure 1. At point 1, the dredge has completed a dump, closed the doors, and is returning to the project site. During this time, the computer is checking two conditions every 2 sec. If the door is closed and the density is less than 1.05 g/cm^3, the computer continues to loop through the checking process. When the slurry density is greater than 1.05 g/cm^3, the computer initializes a load start condition (step 2), recording measurements of bin water volume and initial dredge displacement. From this time forward, the computer checks the condition of the doors (opened or closed) every 2 sec (between points 2 and 3 on the flowchart). When the dredge arrives at the disposal site and opens the doors, the computer initializes a load ending condition (point 4), recording the final hopper volume and final dredge displacement. At point 5, the production calculations are performed. During step 6, a production report is generated, stored in a data file, and printed. When the doors close after the dump, the loop at point 1 begins again. The ALMS updates the computer screen every 2 sec with data output from each sensor.

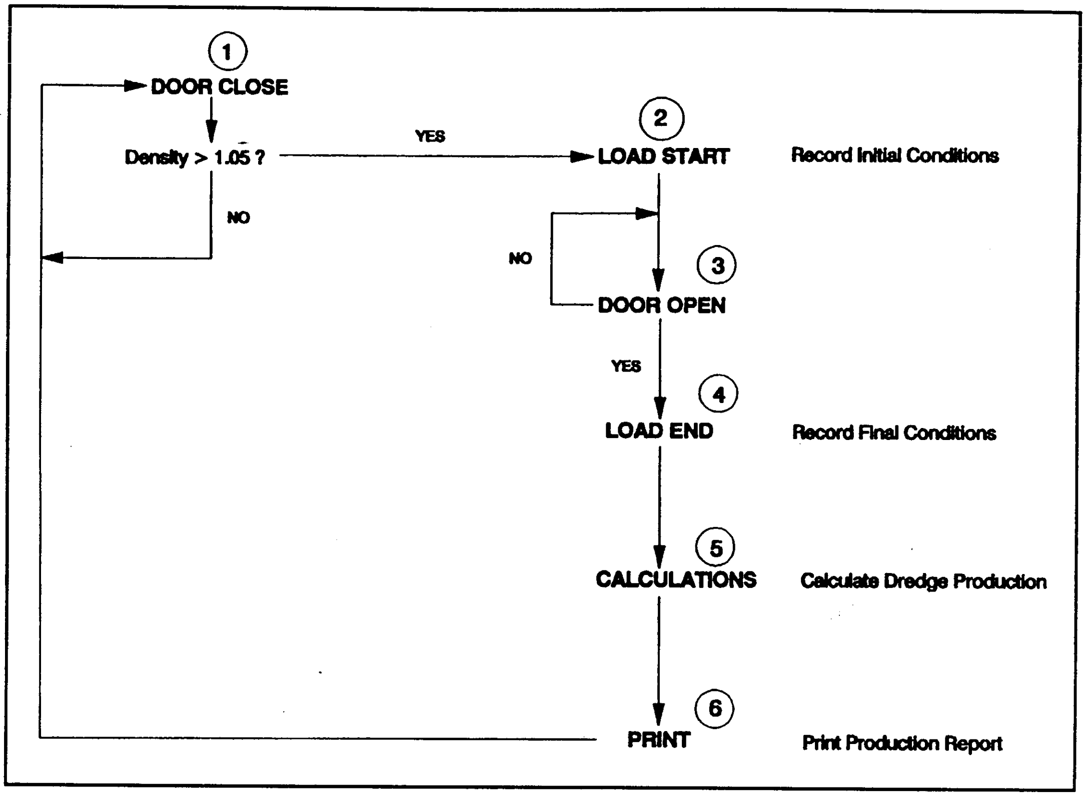

Figure 1. ALMS operation cycle

Testing and Evaluation

The ALMS was tested during the week of August 16, 1993, on the Corps' hopper dredge *Wheeler* at Matagorda Bay, Texas, east of Corpus Christi. The dredged sediments consisted primarily of fine sands with some silt. The in-place density of the sediments was 1.80 g/cm^3.

Seven hopper loads were recorded during the testing and evaluation period. Figure 2 shows the sequencing of the signals from the acoustic sensor (top curve), the slurry density (middle curve), and the hopper doors (bottom curve) for all seven loads. Note that the load starts when the density in the pipe begins to increase and ends when the hopper door relay is tripped. Figure 3 is a plot of the initial and final hopper volume and dredge displacement for load L1 (shown in Figure 2).

To test the accuracy of the system, two water tests were performed, designated as L2 and L3 in Figure 2. The hopper was filled with seawater and emptied. The density of the seawater was 1.025 g/cm^3. The density of the seawater in the hopper was calculated with data output from the ALMS to be 1.06 g/cm^3, which is about 3 percent high. Because the ALMS is designed to operate automatically only when the slurry density in the pipe is greater than 1.05 g/cm^3, the water test data were downloaded from the computer hard disk for analysis. It is possible that

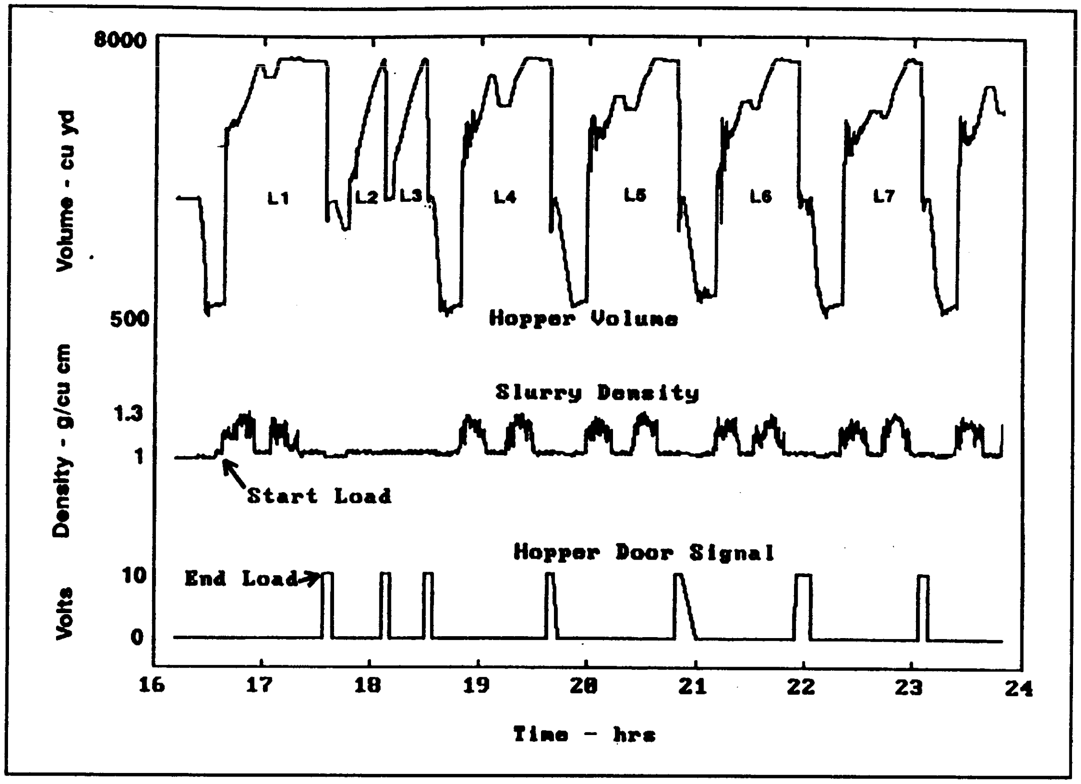

Figure 2. Sequencing of signals from the acoustic sensors, density meter, and hopper door relay

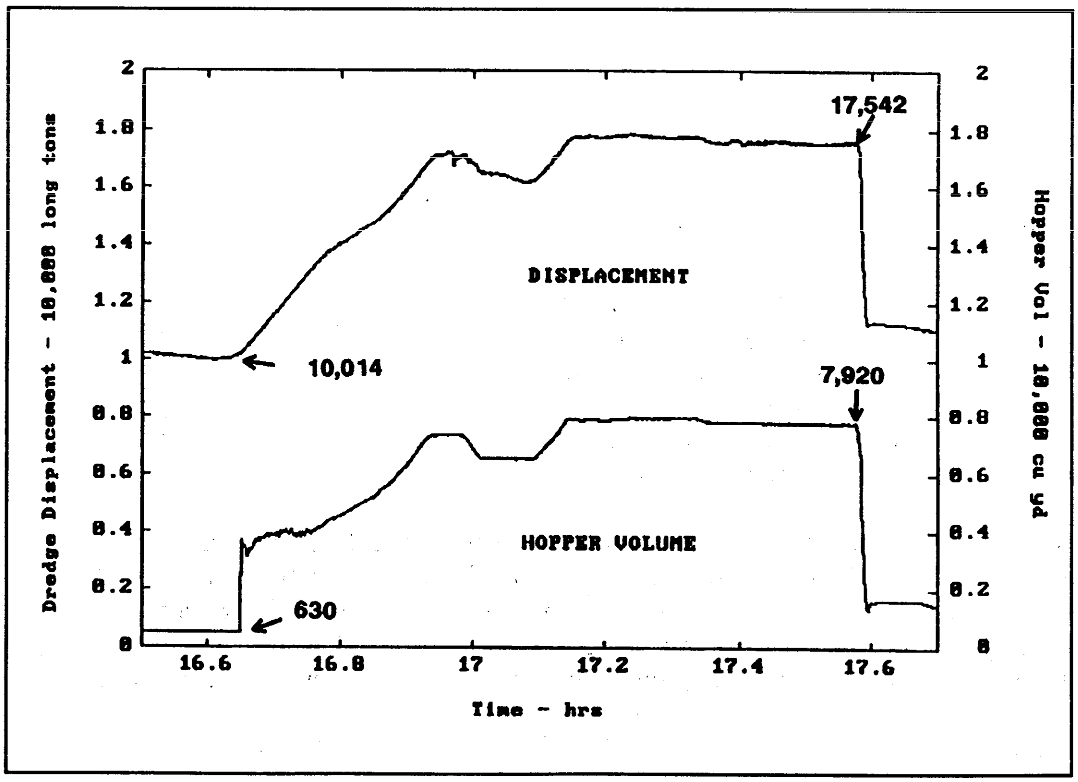

Figure 3. Dredge displacement and hopper volume data for load L1

the discrepancy occurred because only two acoustic sensors were used to measure hopper volume, instead of four.

Figure 4 is a plot of the initial and final volume and displacement for one of the water tests. A load summary for each of the seven test loads is given in Table 1. A sample of the hard copy production report is shown as Figure 5.

Summary

An automated load monitoring system has been successfully designed and implemented. The ALMS uses four instrumented systems to provide data on initial and final dredge load conditions and produces a real-time production report as each load is completed. This system represents a significant advancement in hopper load monitoring technology. It produces an accurate, repeatable measurement of bin water volume for each load, reducing the need for manual measurement or pumping out the hopper to a designated volume. The system produces immediate feedback to the dredge operator on dredge production, with screen updates to allow a visual indicator of real-time hopper volumes and dredge displacement. The computer stores all of the raw sensor data for later analysis or verification, if needed. The data from the production report eliminate the need for time-consuming, manual calculation of production. The accuracy of the instrumentation can be verified through the water test process.

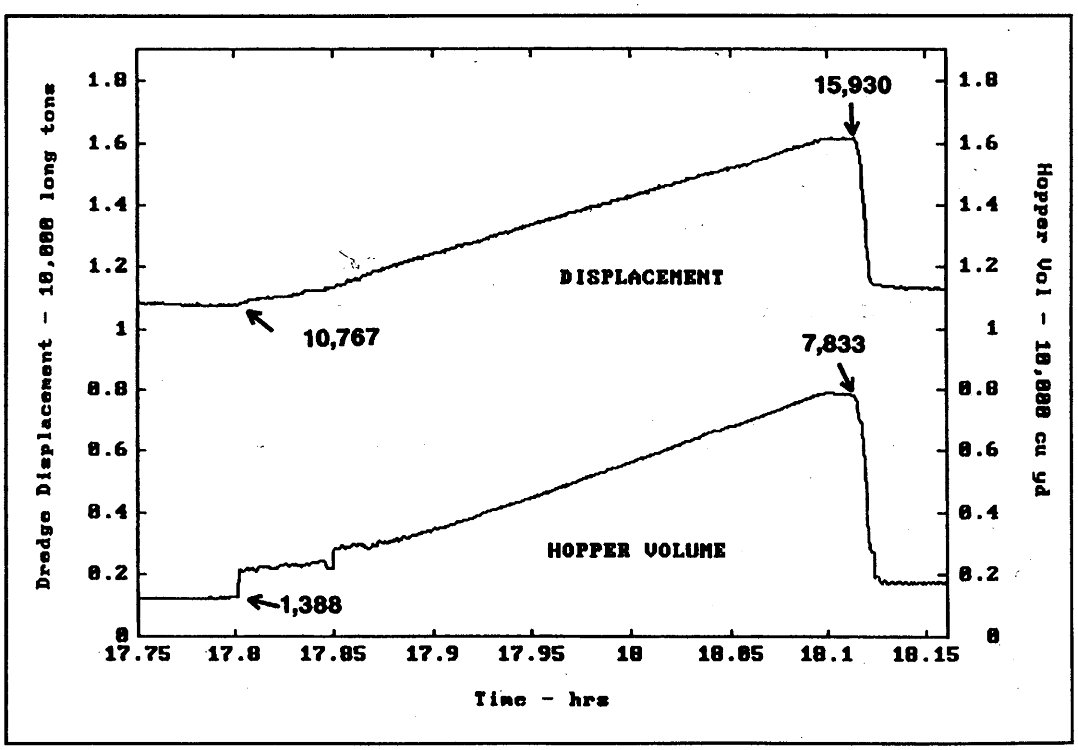

Figure 4. Dredge displacement and hopper volume data for water test L2

Table 1. Load Summary for ALMS Test (20 Aug 93)										
Load	Begin Time hr	End Time hr	Initial Volume cu yd[1]	Final Volume cu yd	Initial Displacement long tons[2]	Final Displacement long tons	Bin Water long tons	Total Displacement long tons	Average Density g/cm³	Production cu yd
1	16.63	17.55	630	7,920	10,014	17,542	485	8,013	1.35	3,321
2	17.78	18.09	1,388	7,833	10,767	15,930	1,070	6,232	1.06	0
3	18.18	18.46	1,894	7,901	11,233	16,070	1,460	6,297	1.06	0
4	18.81	19.61	621	7,926	10,034	17,906	479	8,351	1.40	3,835
5	19.97	20.79	647	7,917	10,091	17,825	499	8,232	1.38	3,626
6	21.15	21.91	691	7,933	10,034	17,542	532	8,040	1.35	3,326
7	22.32	23.02	634	7,946	10,053	17,501	489	7,937	1.33	3,127
Total Cumulative Production										17,235

[1] To convert cubic yards to cubic meters, multiply by 0.7645549.
[2] To convert tons (long, mass) to kilograms, multiply by 1,016.047.

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                    DREDGING PRODUCTION REPORT -- DREDGE WHEELER

DREDGING LOAD STARTED AT  20-AUG-1993   16:37:48
DREDGING LOAD ENDED   AT  20-AUG-1993   17:33:00

LOAD       1                              FILE d:WH930820.BIN

SPECIFIC WEIGHT OF WATER                       1.025 GM/CM^3
SPECIFIC WEIGHT OF SOLIDS                      2.650 GM/CM^3
SPECIFIC WEIGHT OF IN-SITU SEDIMENTS           1.800 GM/CM^3

STARTING VOLUME IN HOPPER                    630 CUBIC YDS
  ENDING VOLUME IN HOPPER                   7920 CUBIC YDS

STARTING SHIP DISPLACEMENT                 10014 LONG TONS
  ENDING SHIP DISPLACEMENT                 17542 LONG TONS

BIN-WATER WEIGHT                         1086400 LBS
TOTAL WEIGHT IN HOPPER                  17949120 LBS
AVERAGE DENSITY IN HOPPER                      1.35 GM/CM^3

IN-SITU HOPPER PRODUCTION                   3321 CUBIC YDS
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Figure 5. Sample of ALMS production report

Reference

Scott, S. H. 1992. "Applying Ultrasonic Surface Detectors to Hopper Dredge Production Monitoring," *Dredging Research Technical Notes* DRP-3-06, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.