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Dredging Research Technical Notes

Controlled Tests of Eductors and Submersible Pumps

Purpose

This technical note summarizes a series of full-scale tests on the US Army Engineer Waterways Experiment Station (WES) Dredging Research Program (DRP) eductor, a commercial eductor, and two commercial submersible pumps. The note covers test equipment, material, and procedures used to evaluate the performance of the eductors and submersible pumps in clean sand and a variety of debris types. Information provided will assist personnel in selecting equipment for specific dredging and sand bypassing applications.

Background

Eductors (jet pumps) are hydraulic pumps with no moving parts, relying instead on an exchange of momentum to entrain the slurry (Richardson and McNair 1981). Eductors have been used for sand bypassing at inlets since the early 1970s with varying degrees of success. Improvements in increased debris resistance and ease of deployment and retrieval were identified as items needed to make eductor sand bypassing more widely applicable, and resulted in the DRP work unit Improved Eductors for Sand Bypassing.

Additional Information

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Description of Eductors and Submersible Pumps Tested

Through a series of contracts, the DRP eductor was designed, constructed, and tested. Some of the design features (Figures 1 and 2) include a smooth cylindrical outer shape to prevent debris (logs and sticks) from jamming in the eductor and making retrieval difficult, a series of fluidizing nozzles around the perimeter of the tip to fluidize the sand for removal and to allow heavy debris to sink below the eductors, a grate over the entrance to prevent debris from entering the suction chamber, and a ring jet to reduce pullout forces.

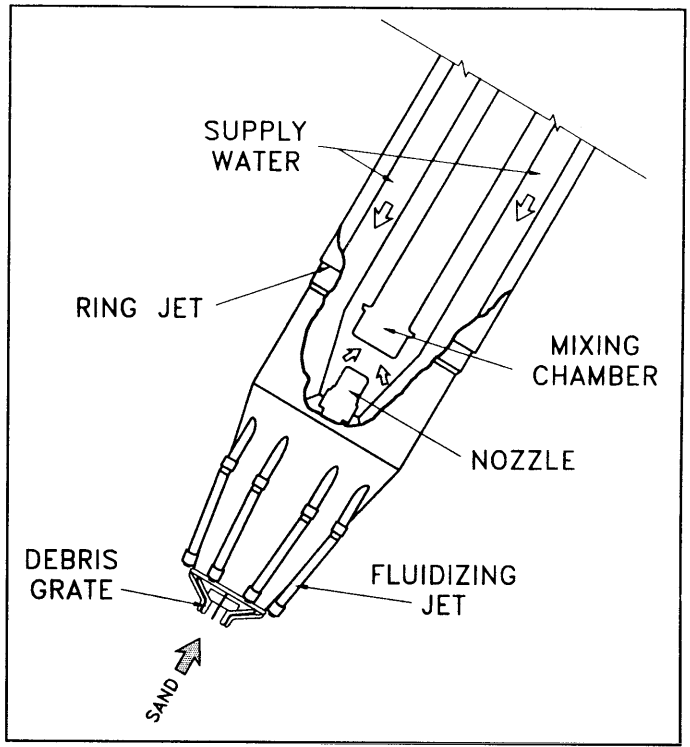

Figure 1. Schematic of DRP eductor

Figure 2. DRP eductor

As a baseline comparison, the eductor used at the Indian River Inlet, Delaware, Sand Bypass System also was tested; see *Dredging Research Technical Notes* DRP 3-03 (Clausner 1990a) for additional details. This eductor, built by Standard Gravel of Franklinton, Louisiana, has the same basic hydraulics as the DRP eductor. However, this eductor has a simple suction duct and a linear manifold of fluidizing nozzles (Figures 3 and 4). The Indian River Inlet eductor has been used successfully for over two years, bypassing over 150,000 cu yd before the test date (by January 1992 the bypass system had transferred over 200,000 cu yd). Testing of the Indian River Inlet eductor provided an excellent standard against which to compare the DRP eductor.

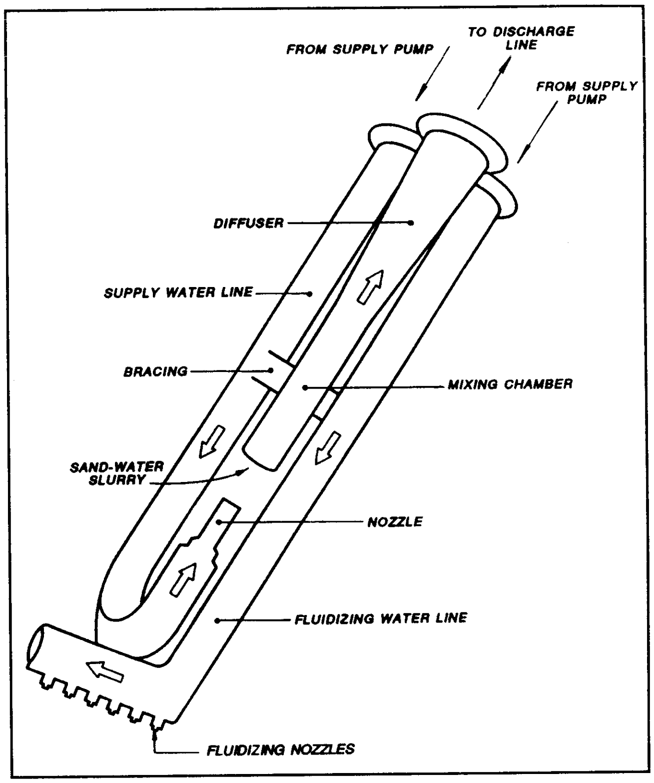

Figure 3. Schematic of Indian River Inlet eductor

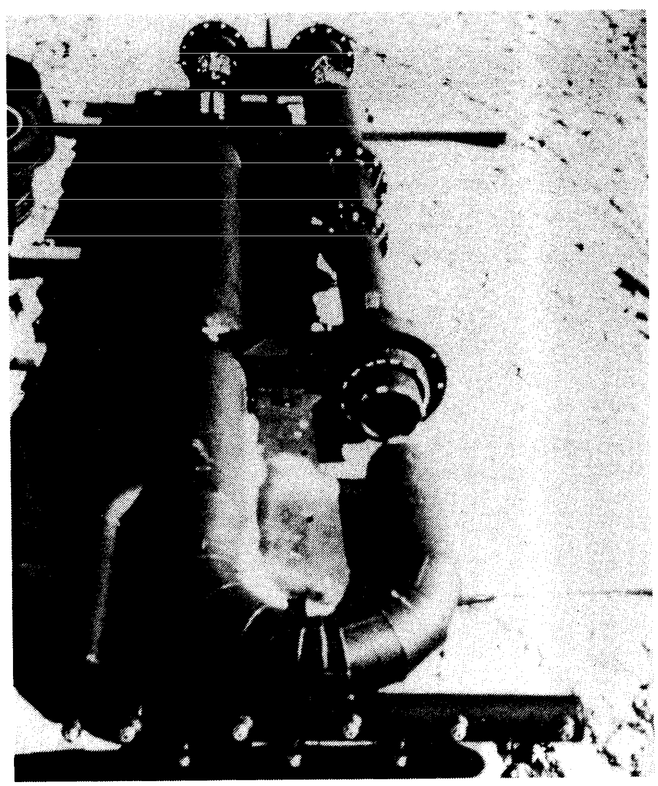

Figure 4. Indian River Inlet eductor

Another facet of the Improved Eductor work unit is to investigate alternatives to eductors with submersible pumps being a likely alternative (Clausner 1990b). Consequently two submersible pumps were included in the testing program. The first pump tested was an H&H model PF50 x 8P 8-in. hydraulically powered submersible pump with a 75-gallon per minute (gpm) (M76 x 5.0) hydraulic motor (Figure 5). The final pump tested was a Toyo DP-150B electrically

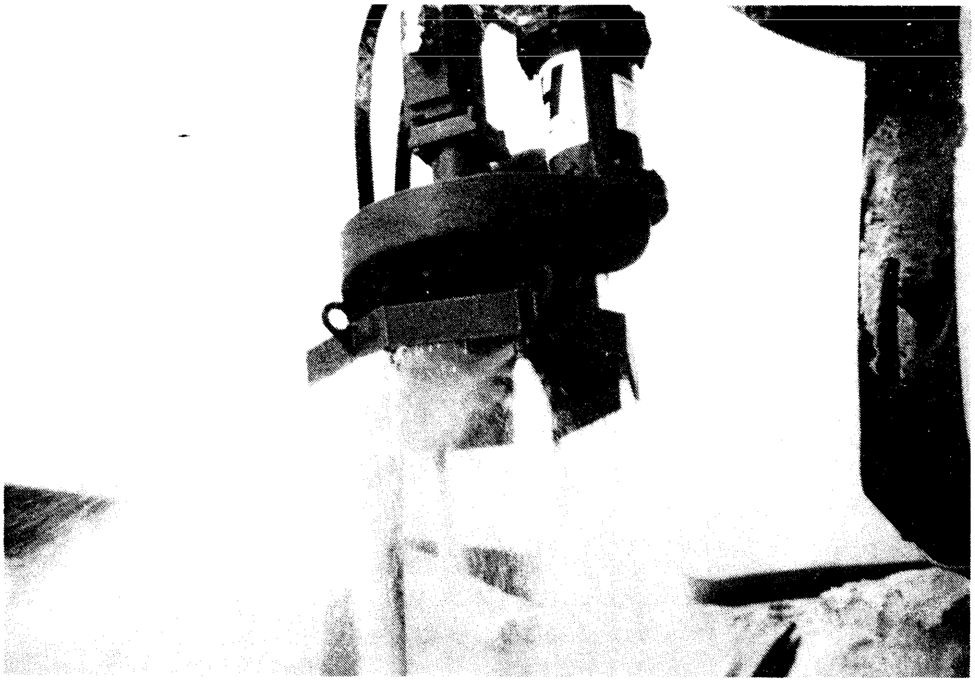

Figure 5. H&H PF50 by 8P submersible pump

powered, 10-in. submersible pump (Figure 6). Table 1 summarizes the characteristics of the eductors and submersible pumps tested.

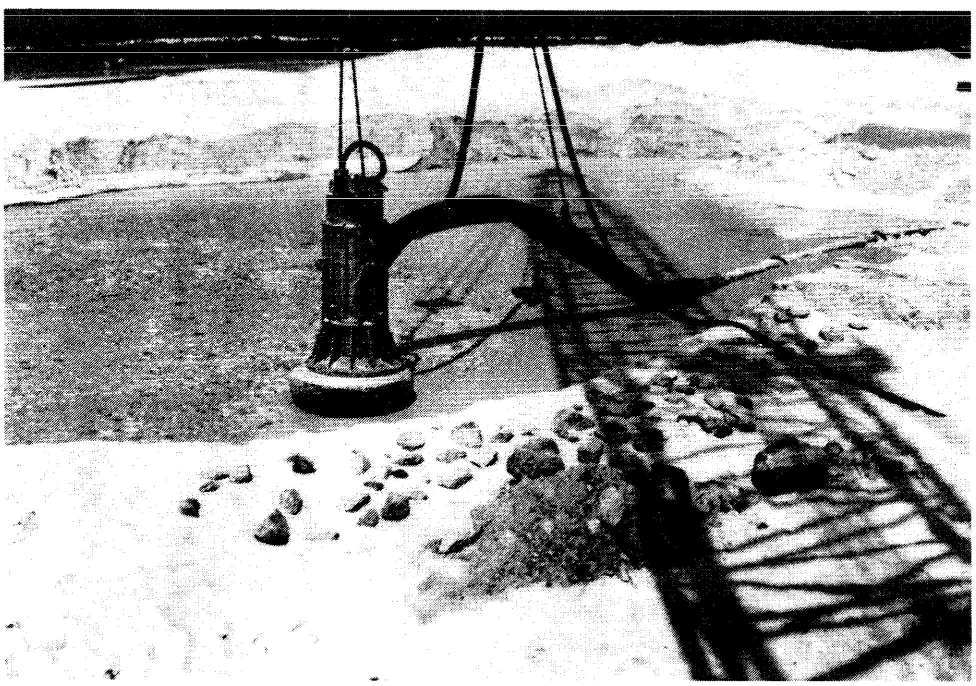

Figure 6. Toyo DP150B submersible pump

Table 1 Eductors and Submersible Pumps Tested*			
Item/ Manufacturer	**Physical Characteristics**	**Power Source Characteristics**	**Average Horsepower Consumed**
DRP Eductor/ Genflo Standard Gravel Company	20-ft-long, 9,000-lb, mixer, 6-in. discharge pipe, 10 in. long	450-hp diesel, pump, 3,300 gpm at 155 psi	300
Indian River Inlet Eductor/ Genflo - Standard Gravel Company	20-ft-long, 3,500-lb, mixer, 6-in. discharge pipe, 10 in. long	450-hp diesel, pump, 3,300 gpm at 155 psi	300
H&H Model PF 50 x 8 with 20 percent chrome and nickel inlay	3-ft-long, 3-ft-wide, 724-lb, max. spherical solid, 4-in. discharge pipe, 8 in. long	275-hp diesel, hydraulic pump, 75 gpm at 2,000 psi	150
Toyo DP-150B high chrome pump with external agitator	8-ft-long, 3-ft-diameter, 8,000-lb, max. spherical solid, 4-1/2-in. discharge pipe, 10 in. long	300-hp diesel, generator	150-200

* The last column is an estimate of the horsepower required from each power source by each pump during operation. The eductors only require about a 300-hp diesel for actual operation. The H&H pump used is normally supplied with a 150-hp power source; the larger unit used was only one available at the time of the test. The Toyo pump requires a high starting horsepower, but only consumes 150-200 hp during operation.

Test Location

The tests were conducted at Standard Gravel Company's Enon, Louisiana, gravel pit (approximately 65 miles north of New Orleans). The availability of support equipment and electrical power and the relatively close proximity to the US Army Engineer Waterways Experiment Station (WES) made this site attractive. This site was selected because it also closely simulates applicable conditions at coastal bypassing locations.

Test Layout and Equipment

The test location has a large area of clean sand (mean diameter, 0.3 mm, less than 5 percent fines) in excess of 25 ft thick that could be saturated to simulate sand bypassing at a coastal location. The test site setup was nearly identical for both the eductor and submersible pump tests (Figure 7). The site encompassed an area approximately 300 by 450 ft and had a portable building where instrumentation used to monitor performance and archive test data was housed. Table 2 gives characteristics of the pumps used during the tests. A large crane (110-ton, 100-ft-long boom) was used to deploy the eductors and submersible pumps. A 3-cu yd backhoe, an 18-ton boom crane, and a bulldozer were also used to move pipe, grade sand, and perform other operations.

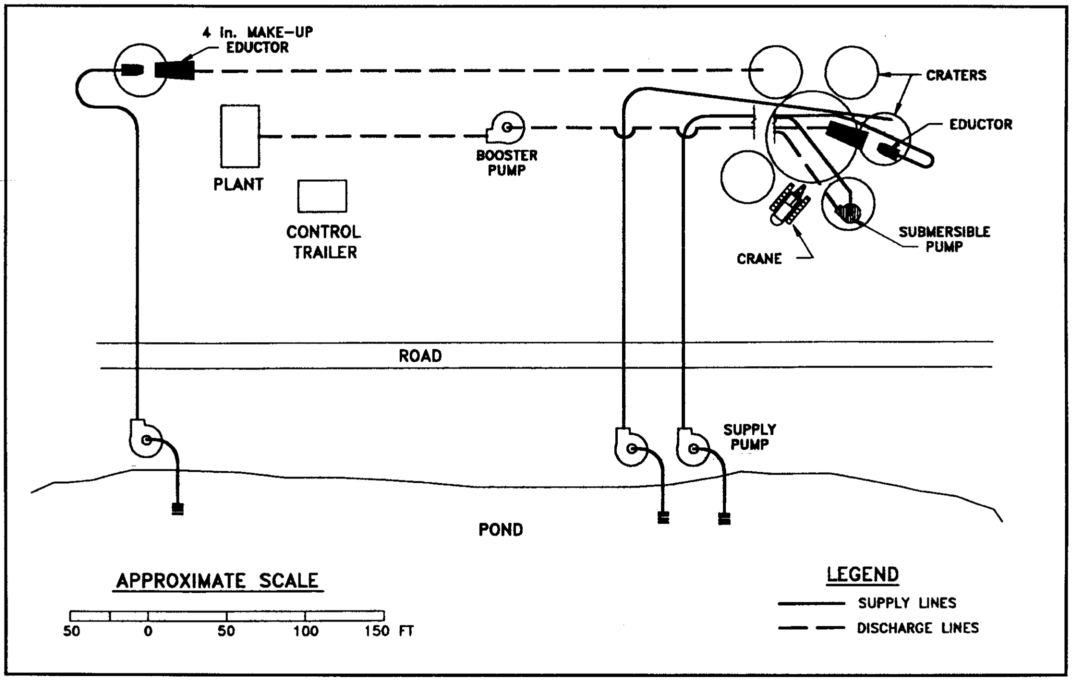

Figure 7. Test site configuration

Table 2
Water Pumps Used during Tests

Equipment	Horsepower	Flow Rate, gpm
Makeup water to crater	250	3,000
Inline booster	180	3,300
Supply pump for return eductor	180	1,500

Conditions at coastal sites were simulated by saturating the crater test area. This was done by pumping water to the crater before and during tests at a rate sufficient to keep the crater filled with water.

During the eductor tests, motive water to the eductors was provided by a supply pump from an adjacent pond through a 10-in. ID steel pipeline about 250 ft long. Slurry dredged by the eductors and submersible pumps flowed through an 11-in. ID high-density polyethylene (HDPE) pipeline to a booster pump. Discharge from the booster pump went through a 10-in. steel pipeline to a processing plant (classification tower with a 1-1/2 in. square grid grizzly), which was used to separate debris from the sand. The 30-ft tower minus the 10-ft drop in elevation from the booster pump to the bottom of the tower resulted in a 20-ft vertical lift. Sand separated by the processing plant was recycled back to the primary test area using a 4-in. eductor powered by a separate supply pump.

Instrumentation included pressure gages on the discharge side of the supply pump, at the inlet to the booster pump, and on the discharge side of the booster pump. A nuclear density meter and doppler flow meter were mounted on the vertical section of pipe attached to the processing plant. Pressure data, slurry velocity, slurry percent solids (by weight), and production (cubic yards per hour) were displayed and recorded on a personal computer after passing through a signal-conditioning unit. The hardware and software used to collect the data were originally developed under DRP work unit Production Meter Technology. For this test, the software was expanded considerably to allow display and user-friendly operation. WES Instrumentation Services Division developed the software and the signal-conditioning unit and installed the pressure transducers. Overall, the data collection system worked extremely well, with data being collected every 10 sec during the tests.

A video camera aimed at the test crater was used to document each test. A second video camera was focused on the computer screen as a backup in case of failure by the computer to record the test data.

Test Procedures

Pressure transducers were calibrated before testing (calibrations were stored in the computer) and the nuclear density meter was equalized daily (a two-hour warmup period). Predetermined motive water pump and booster pump pressures were established before the eductor test trials, as was the booster pump pressure for the submersible pump test trials. Each unit's production capacity was tested in "clean" sand and in sand-debris combinations for a 30-min duration of continuous performance in each test. Three separate trials were conducted for each combination in almost every case. For a limited number of cases only two runs were made.

The crane was used to deploy the eductor or submersible pump and reposition it as needed during each trial. The same crane operator was used for all the tests conducted with different types of pumps and debris combinations. The debris combinations were laid on clean sand in a random pattern within a radius of approximately 15 ft around the point of application of the pump. As the unit excavated sand, the debris would "fall" into the crater. This method was used because debris in sand bypassing operations is encountered in a similar manner.

During the trial, when a substantial drop in percent solids was observed, the pump was lifted from the crater bottom and swung to the left or right approximately 5 ft and then set back on the bottom. This kept the pump in the debris field yet allowed it to possibly clear itself. During the stone debris trials it was observed that stones too large to enter the pump would accumulate in the bottom of the crater and form a barrier between the pump and sand, thus reducing production rates. The repositioning of the pump would allow it to excavate sand on the fringes of the consolidated barrier and pump slurry at higher rates until the process repeated itself. A video camera recorded the pump in the crater during the trial and documented debris accumulation at various locations (at the grizzly, in the booster pump stone box, or pump suction duct).

Under certain conditions, the submersible pumps could acquire slurry at very high percent solids concentrations (sometimes exceeding 60 percent solids by weight). At this point the discharge line was susceptible to being plugged if a slope cave-in temporarily choked the pump or if the pump momentarily lost power. At these times the operator would raise the submersible pump 1 or 2 ft to reduce solids concentrations. It was not always possible to give the operator sufficient notice to prevent plugging the line.

At the completion of each test with debris combinations, the crater area would be contaminated by debris that was too large to be transported by the system or that did not come into contact with the pump. Because of this, the contaminated area was surveyed by conventional methods, its position logged, and it was not used again. The flexible plastic HDPE pipe allowed the pumps to be redeployed in uncontaminated areas immediately adjacent to the previous debris trial.

The sand and debris combinations consisted of the following materials:

- Clean sand with a mean diameter of 0.3 mm and less than 5 percent fines.
- 16 cu ft of cut wood that varied in length from 1 to 3 ft with the diameters varying from 1 to 6 in. Before the tests, the wood pieces were soaked in water to produce a negative buoyancy which caused them to sink to the bottom of the crater during the trial.
- 16 cu ft of stone riprap ranging in size from 2 in. to 18 in. with a mean diameter of 7 in.

- 60 garbage-bag sized plastic liners (weighted with sand) and 15 "swim fins" fabricated from 3/4 in., 4-ply conveyor belt cut into 9- by 24-in. rectangular pieces.

- Aluminum beverage cans (punctured to sink). About 500 were tested in one jet pump trial with no apparent effect on production (minute pieces of shredded cans were observed at the grizzly) so the use of this debris was discontinued.

- Kelp. Kelp was donated by the San Diego Parks and Recreation Department, but the test runs with this debris were discontinued due to the kelp's increasing rate of deterioration and negligible effect on production rates. Had fresh kelp been available, it likely would have had a measurable impact on production.

In addition to the debris tests, the DRP eductor was tested for ease of deployment and retrieval. The deployment tests consisted of measuring the time required to sink the unit to a depth of 18 ft using only the fluidizing jets. By modifying the fluidizing jets so that the rear two jets pointed back toward the deployment frame with the remaining jets pointed straight down, the unit sunk to design depth in 90 sec.

During the retrieval tests, the deployment frame was removed to allow the eductor to sink vertically into the sand a distance of 18 to 20 ft. Then a series of pull tests were done with the crane acting through an inline load cell. Variables tested included the amount of time the unit was allowed to sit and the active assistance of the three hydraulic units — the fluidizing jets, the ring jet, and the eductor itself. Pullout loads ranged from 34,000 lb to 10,000 lb. The most important factor in keeping pullout forces to a minimum was allowing the sand around the whole unit to become fully fluidized, thereby reducing skin friction and preventing a vacuum. This was accomplished by operating the eductor and blocking the discharge line, and/or using the ring jet or fluidizers. The higher flows achieved by blocking the eductor discharge line (so all the water exits the open end of the eductor) provided the quickest saturation of the sand. However, the other two methods also were effective. It was concluded that the ring jet was not needed.

Results and Discussion

Sixty-one tests were conducted, with 48 of the tests meeting the WES criteria of 30 min of continuous performance. The average production rates for each set of tests are contained in Table 3. The DRP eductor and the Indian River Inlet eductor had very similar performance in clean sand, about 350 cu yd/hr. As expected, performance was reduced substantially in debris. The DRP eductor was measurably better in stone (244 versus 203 cu yd/hr) and garbage bags and swim fins (215 versus 186 cu yd/hr). The Indian River Inlet eductor was superior in wood (322 versus 269 cu yd/hr).

Table 3 Test Results Summary		
Equipment Tested	**Debris Type**	**Average Production Rate, cu yd/hr**
DRP eductor	Sand	355
	Stone	244
	Garbage bags and swim fins	215
	Wood	269
Indian River Inlet eductor	Sand	346
	Stone	203
	Garbage bags	186
	Wood	322
H&H submersible pump	Sand	221
	Stone	84
	Garbage bags and swim fins	188
Toyo submersible pump	Sand	375
	Stone	403
	Garbage bags and swim fins	322
	Wood	241

Of the two submersible pumps, the Toyo pump had consistently higher production in clean sand and all types of debris, while the H&H pump had the least amount of production of any unit tested. It should be noted that the H&H pump was an 8-in. pump, while the eductors and Toyo pump were 10 in. Had a 10-in. discharge coupling that attached directly to the pump housing been available for the H&H pump, an increase in production rate of up to 15 percent probably would have been possible (personal communication, Mr. Howard Stovall, Vice President, H&H Pump Company, January 24, 1992). This potentially would have raised production rates for the H&H pump to 254, 97, and 216 cu yd/hr in sand, stone, and garbage bags and swim fins, respectively. The H&H pump was more prone to plugging of the discharge line than any of the other units tested, having three instances where the line was plugged. A considerable amount of operator attention to raising and lowering the H&H pump to achieve maximum production and prevent plugging of the discharge line was required.

The Toyo pump was a much larger, heavier unit than the H&H pump. It also is much more expensive. Purchase price for the Toyo pump as tested was estimated at $73,300. The purchase price of the 8-in. H&H pump was approximately $15,300. The Toyo pump had the highest overall production of any unit tested, over 400 cu yd/hr. The improved production in stone versus sand was probably due to the operator gaining experience with the Toyo pump. The garbage bags and swim fins had an appreciable impact on production, reducing it to 322 and 241 cu yd/hr, respectively. The Toyo pump also was very sensitive to operator control, with relatively constant raising and lowering of the unit required to maintain high production and prevent plugging of the discharge line.

Conclusions

In clean sand, performance of the DRP eductor and the more conventional Indian River Inlet eductor are about the same. Performance in debris was a function of the type of debris. The grate on the DRP eductor keeps out stone and garbage bags/swim fins better than the Indian River Inlet eductor; however, the grate is more prone to clogging with wood. The Indian River Inlet eductor is more susceptible to stones entering into the suction chamber, thereby reducing performance.

The H&H pump in its present form is not well suited to the types of debris tested. It is very susceptible to both rocks and wood. A rock guard, relatively easily fabricated (and also available from the manufacturer), could help solve these problems, though probably reducing performance somewhat.

The Toyo pump performed the best overall and was only bettered by the Indian River Inlet eductor when pumping wood debris.

The lack of a requirement for constant operator control and the relative immunity to line plugging make the eductors well suited to long-term bypass operations. The choice of a particular eductor will depend on the type and amount of debris present. The Toyo pump's high production and apparent ruggedness make it a possible candidate for bypass operations (particularly those not suited for eductors), but the level of operator control required to achieve the high production rates and the potential for line plugging must be considered. The H&H pump's low cost and light weight (approximately 724 lb) make it well suited for smaller, aperiodic bypass and dredging jobs.

The Vicksburg District's Monroe Navigation Field Office used similar logic before purchasing a lightweight submersible pump to maintain locks and dams on the Red River. For small aperiodic dredging jobs, the purchase price can be a more important factor than production rate.

A detailed description of the tests will be published in a future DRP report.

Acknowledgements

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