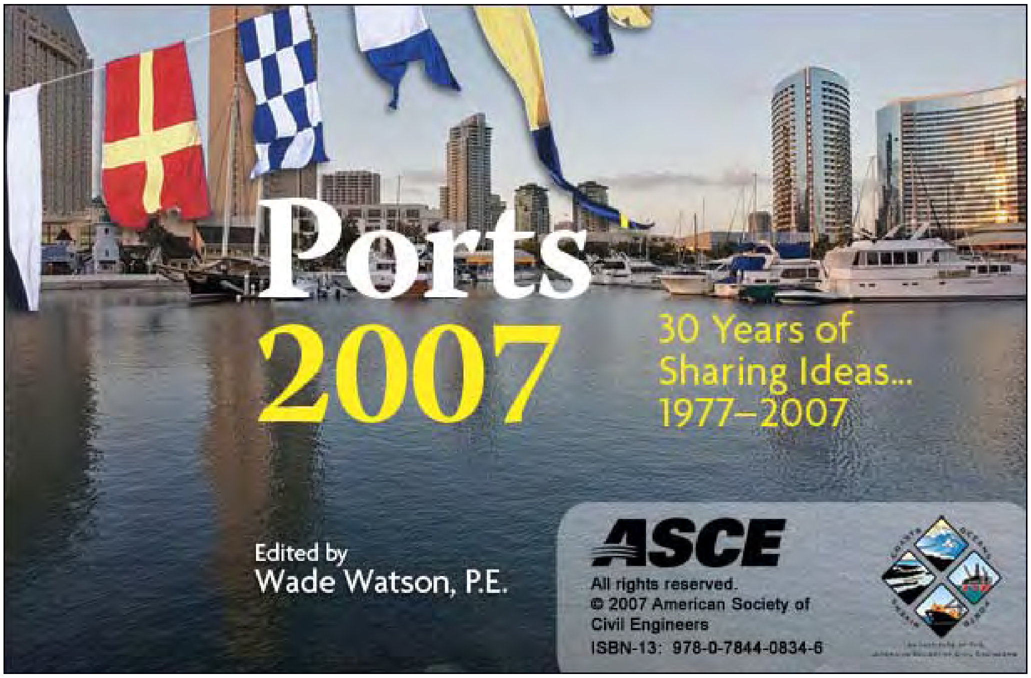



# A Potential Alternative to Berth Maintenance Dredging

Joe T. Bryant, P.E.
Marianne D. Moseley
South Carolina State Ports Authority
P.O. Box 22288
Charleston, SC 29413-2287

# A Potential Alternative to Berth Maintenance Dredging

**Joe T. Bryant, P.E.**
**Marianne D. Moseley**
**South Carolina State Ports Authority**
**P.O. Box 22288**
**Charleston, SC 29413-2287**

## Introduction

The South Carolina State Ports Authority's Columbus Street Terminal is located on the right descending bank of the Lower Town Creek Reach of the Cooper River in Charleston, South Carolina. The 3875' pile supported concrete wharf structure is situated parallel to the channel, but the lower 1640' is canted 10 degrees inland. The reach widens on the lower end with the channel flow going away from the wharf. Significant silting was experienced on this lower end. The channel and berth are authorized to -45' MLW. The lower 1640' of berth was dredged to -53' MLW every four months to maintain the authorized depth.

The total cost to maintain depths on the lower end was approaching $1 million per year. Each 4 month dredging removed approximately 80,000 cubic yards. The dredging cost averaged about $250,000.00 per cycle or $750,000.00 per year. The material was placed in nearby confined disposal facilities. Maintenance of the disposal areas averaged approximately $250,000.00/year. Dredging operations had to be worked around vessel activity and typically took 4-5 days per cycle. Scheduling the dredge often became difficult and prices could significantly vary with dredge availability. Delays in dredging the berth created operational problems and vessel groundings. Fortunately, the soft bottoms never damaged the vessels.

In the late 1980's a new technology was developed by the Navy to control sedimentation in estuarine and fluvial berthing areas. The technology was commercially installed in Terminal #4 at the Port of Grays Harbor in Washington in 1987. Certain sediments will form a layer of fluid mud during periods of slack water between tides. Those sediments may be kept in suspension or re-suspended by introduction of flow into the water column. Kept in suspension, they then would be carried out of the berthing area on the next tidal flow. The new technology consisted of a series of water jets to keep the fluid mud in suspension until the natural water flow carried it out. The jets put energy into the water column during times of slack water when siltation typically occurs.

Generally, the technology can best be applied to those sediments that have high silt/clay content and settle slowly from the water column. Sandy type materials tend to quickly settle and are not as easily kept entrained. The technology depends upon the natural flow of the stream. However, the system can be designed to operate in streams flowing as little as 0.25 knots. The systems can operate in fresh or saline conditions and can protect berthing areas up to 250' wide perpendicular to the face of the wharf.

## System Description

The system consists of multiple water jets powered by hydraulic motors. Water is taken in through an intake screen up in the water column, moved downward through the unit by a hydraulic driven impeller (less than 500 rpm), and discharged horizontally at the mud line. The water jet moves high volumes of water axially through the unit at low differential pressure. The water discharged from the jets keeps the sediments from settling and forming shoals in the berth.

Capture velocities at the intake are relatively low. They are in the range of 2.5 ft./sec. at the screen and drop to about 0.5 ft./sec. four feet away. This is less than the swimming ability of most fish. If they do enter the area around the intake, they are able to easily escape. Clearances through the unit are such that smaller fish that may be drawn into the intake will pass the impeller and be discharged without harm. Studies have been done on the probability of fish impact. A two inch fish has only a 20% probability of impact if it is actually drawn into the unit. Most fish this size and greater would easily be able to escape capture.

Discharge volumes and flow rates are sized based upon berth, sediment, and stream characteristics. In general, the units produce high volume at low discharge pressures. Figure 1 shows a water jet.

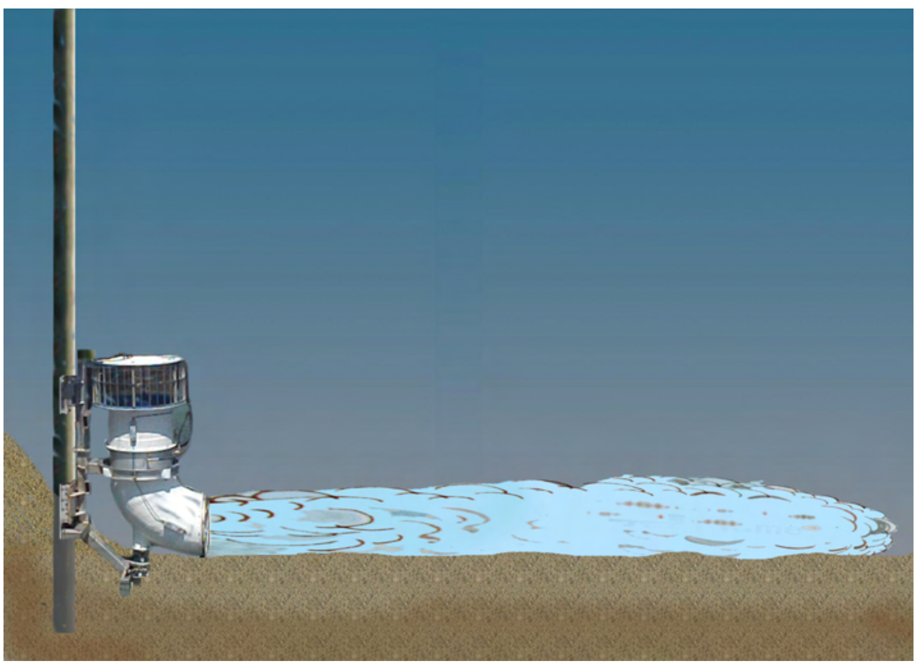


Figure 1: Water jet suspends sediment

The water jets are arranged along the face of wharf and located just behind the fender system. The area in front of each jet needs to be free from obstructions such as pilings. The location of each unit behind the fender system protects the units from vessel contact (Figure 2).

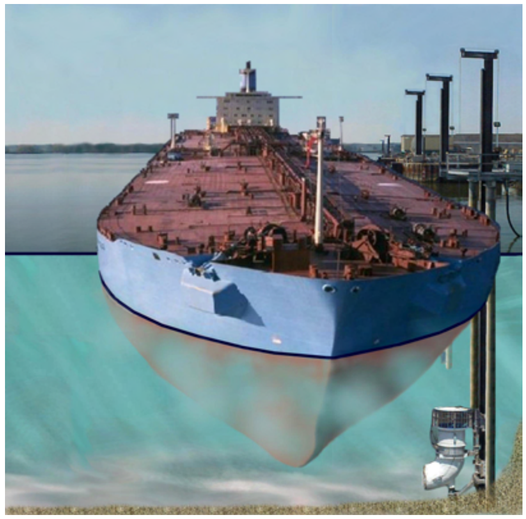
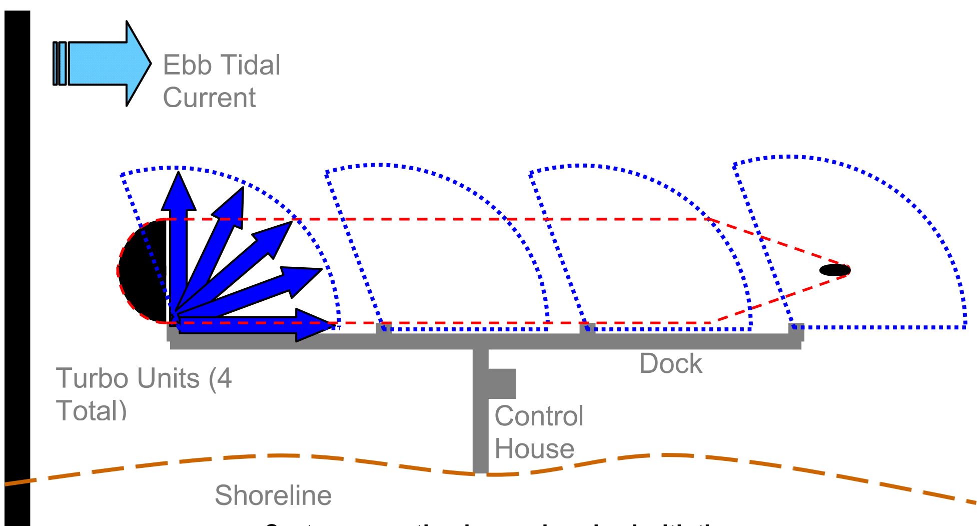


Figure 2: Water jet relative location

Each unit operates in sequence and can fan 180 degrees. Typically, a unit's initial position is perpendicular to the wharf and the fan motion is in the direction of tidal flow. When the first unit's sweep has been accomplished, the next unit begins operation. This continues until all units have operated. Cycle rates are set based on sediment and flow characteristics. The system may be set to begin operation at slack water and each unit sweep outward in sequence on an ebb tide. The system may then remain at rest until the next slack water and sweep inward on the flood tide, thus operating about 3 hours of each 6 hour tidal cycle. If necessary, the units may be set to operate during longer periods of the tidal cycle, continuing operations further into the ebb or flood tides. Figure 3 is a diagram of a typical operation.




**System operation is synchronized with the tides**

Figure 3: Operational diagram

A four unit system is depicted. The four water jet units would be powered by a common hydraulic pumping unit. The pumping unit would be located in a control house convenient to the dock and water jets. Hydraulic piping would connect from the pumping unit to each water jet. Typically, this piping would be located under the dock. The piping must be insulated to maintain hydraulic fluid temperatures in an acceptable operating range. The system must be designed for up to 3000 pounds per square inch operating hydraulic pressure. On the ebb tide the first unit would sweep the path indicated. Each unit would then sweep in turn. The sequence would be reversed on a flood tide.

**The Charleston System**

The Charleston project consists of two hydraulic units powering 5 water jet units each. Each hydraulic unit is skid mounted and complete with oil reservoir, filtration system, oil heating/cooling system, and pressure control and relief devices. The hydraulic fluid is vegetable oil. Vegetable oil has no detrimental effects on the environment. Figure 4 shows the 125 horsepower pump and 150 gallon reservoir. Actual energy consumption is estimated at 90 hp each. The heating/cooling units are separately mounted.

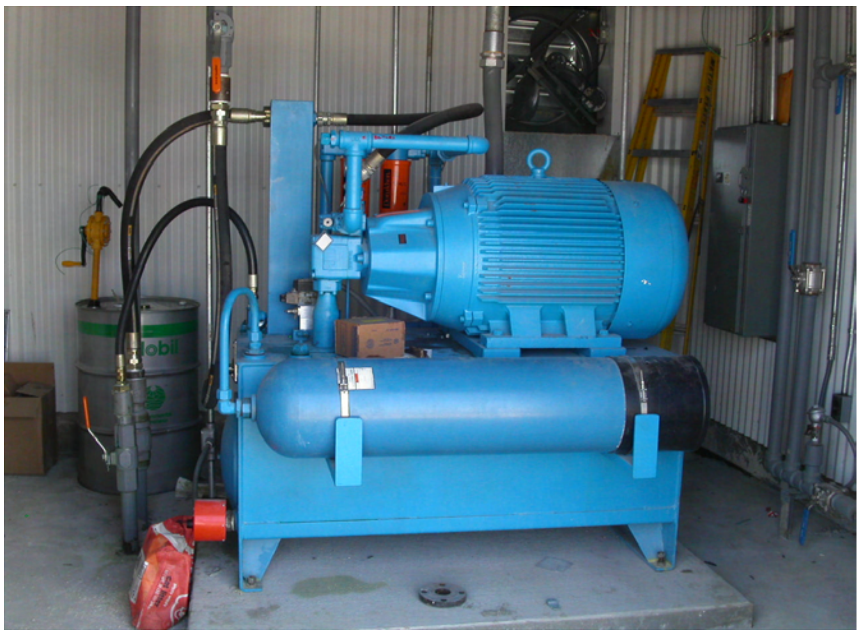


Figure 4: Hydraulic pumping unit

The water jet units are 36 inches in diameter and approximately 15 feet tall, Figure 5. They are capable of a 180 degree horizontal sweep. The water intake is at the top of the unit and includes a screen with openings about 3 inches wide. The unit is axial flow and the hydraulic driven impeller is located in the green center section below the intake screen. The unit is rotated by a hydraulic cylinder located below the discharge nozzle. Two shoes are mounted on the frame assembly that slide over the flange of an H piling. Each unit is mounted on the flange of an H piling and can be slid up the flange for easy servicing. The pilings for the Charleston system are driven on a batter to fit the units below the dock. The support frame and mounting shoes are arranged so the unit will be positioned vertically on the batter pile. Figures 6 & 7 show the attaching bracket on the H pile flange.

Figure 5:  Water jet unit

Figure 6:  Mounting bracket

Figure 7: Jet attached to H pile

The length of berth to be protected determines the number of water jet units. The hydraulic pumping unit is sized based on the size and number of the water jet units it will power. Since the water jets run in sequence, the number in each system is based on the expected run time for each jet. Each jet must operate once between tide cycles. Charleston's ten jets are equally spaced 175 feet apart along the 1640' of wharf to be protected.

**Description of Operation**

Each of the two systems in Charleston operates in parallel. The systems have an oil temperature operating range from 75 to 125 degrees Fahrenheit. Appropriate, heating, cooling, and insulation are provided to maintain the hydraulic fluid and system at acceptable operating temperatures. The system operating pressure range is from 1500 to 3000 psig. Each hydraulic system is charged with approximately 600 gallons of vegetable oil and is powered by a 125 horsepower electric motor.

In addition to the hydraulic pump, the system is equipped with oil heaters and coolers. It is expected with Charleston climate heaters will be used infrequently and coolers only during the hottest days of summer. The combined pumping and heating/cooling system of each system is estimated to actually draw about 90 hp during operation. Electricity is the only required utility other than a phone line for a remote PC connection.

The systems are controlled by software run on a PC. The system operations may be remotely monitored and adjusted. Parameters that can be computer adjusted include:

- Initial and final sweep position
- System initiation relative to tidal conditions
- Duration of operation of individual units and the total system

The controller software is designed to calculate the tides so the units' operation may be programmed for the most productive time in the tidal cycle.

The first water jet is programmed to activate about one hour after high or low tide. It starts in a position to discharge perpendicular to the wharf and sweeps 90 degrees in the direction of stream flow. Each of the remaining jets in the system then activates sequentially. The entire system cycle takes approximately 3 hours. It is important to note that the operation of the jets is fully controllable from the computer console and may be adjusted as required to achieve the desired results. At the conclusion of the cycle, the system shuts down until the appropriate initiation following the next tide.

**Maintenance**

The underwater pumping units are mounted on an H piling and may simply be slid up the piling out of the water for maintenance. They are connected to the hydraulic piping system under the wharf by hydraulic hoses. Maintenance and inspection of hoses is also accomplished by lifting the units up.

The balance of the system is simply a hydraulic system. Routine maintenance would include inspection of hydraulic fluid condition and level, cleaning of filters, inspection of heaters, inspection of pipe insulation, and inspection of pressure relief devices.

**Cost & Justification**

The total cost of the Charleston system installed was about $4.2 million. This included engineering design, system components, wharf modifications, installation, and start-up. Annual maintenance is estimated to be $25,000 per year. Annual electrical power costs are estimated at $35,000. Assuming a 10 year life before major maintenance, the return on investment is expected to approach 20% with the payout slightly over four years.

**Regulatory and Permitting**

For the appropriate conditions this technology can significantly reduce the cost of berth maintenance. Additionally, it provides continuous berth maintenance without the periodic operational disruptions required by conventional dredging. Since maintenance occurs continuously, the periodic significant impact to the water column and bottom by dredging is also avoided. Yet, even the consideration of this technology is sometimes opposed by regulators.

With annual berth maintenance cost approaching $1 million per year, the Port of Charleston was able to garner political support for consideration of the new technology. Also, a system had recently been installed by the Georgia Ports Authority at their Garden City Container Terminal. The State regulators seemed to have more environmental concerns than their Federal counterparts. The U.S. Army Corps of Engineers Regulatory Division basically looked to the State for the section 401 water quality certification. While the Corps dredging group expressed concerns that the system would simply move the dredging burden from the berth into the Federal channel, Corps regulators pointed out that this situation had never materialized in other locations where systems have been installed.

The State's concerns were fourfold:

1. Ultimate disposition of the materials
2. Potential for scouring and increasing entrained solids
3. Impacts on water quality
4. Impacts on fish

The State regulators initially asked for a testing protocol to fully track entrained sediments. It was a typical response of asking for information that could not be provided. The South Carolina State Ports Authority pointed out there was no practical way to differentiate sediments impacted by the proposed system from other sediments in the waterway. Instead, they requested their sister State Agency, the South Carolina Office of Coastal Resource Management to provide a testing protocol that could be accomplished and that would fairly evaluate the impact on the environment.

The regulators could not provide specific standards of water quality to be met. They acknowledged that water quality varied during the year and was affected by many factors. With political pressure to "find a solution" agreement was finally reached on a testing protocol.

**Testing Protocol**

Testing the Charleston system basically involved setting a boundary and comparing conditions when the system was operating to ambient conditions and during normal dredging operations. A boundary was established 150' off the face of the dock and extending 300' upstream and downstream of the end of the dock. Three sample points were established along this line. For ambient conditions an additional upstream and downstream sample point well away from the dock was established. A sixth sample point was established at a nearby marina to address their specific concerns. These are shown in Figure 8.

Dissolved oxygen and turbidity were semi-continuously monitored at one foot below the surface and four feet above the bottom. The bottom was determined using bathymetric soundings using the 28k Hz frequency setting on the sounding unit. Semi-continuous monitoring was defined as every five minutes for 25 hours. Total suspended solids point samples were also taken at these locations at the same depths and at 20 feet below the surface. This set of samples constituted a "sampling event". A sampling event was conducted during a typical dredging process (dredging event) and 48 hours after the conclusion of dredging (post-dredging event). After the system was installed, sampling events were to be conducted during weeks one, three, five, fourteen, twenty seven, forty, fifty three, and sixty six. Sample results from these events were to be compared to sample results from the dredging and post-dredging sampling events. Additionally, a graph of dissolved oxygen and turbidity was to be made for each event coordinated with the tidal cycle.

Bathymetric surveys were also to be made before system operation and after six months and one year of operation. The purpose of the surveys was to verify system operation and to look for evidence of scouring. Observations were also to be made around the units during testing for impacts on fish.

If sampling events or bathymetric surveys gave indication of adverse impacts to the water quality or evidence of scouring, the system would be "de-tuned" by regulating the sweep times and duration or by slowing the impellers on the water jets. This would effectively reduce the energy being placed into the water column and reduce the impact on entrained sediments. If impacts on fish were observed, the openings on the water intake screen were to be lessened.

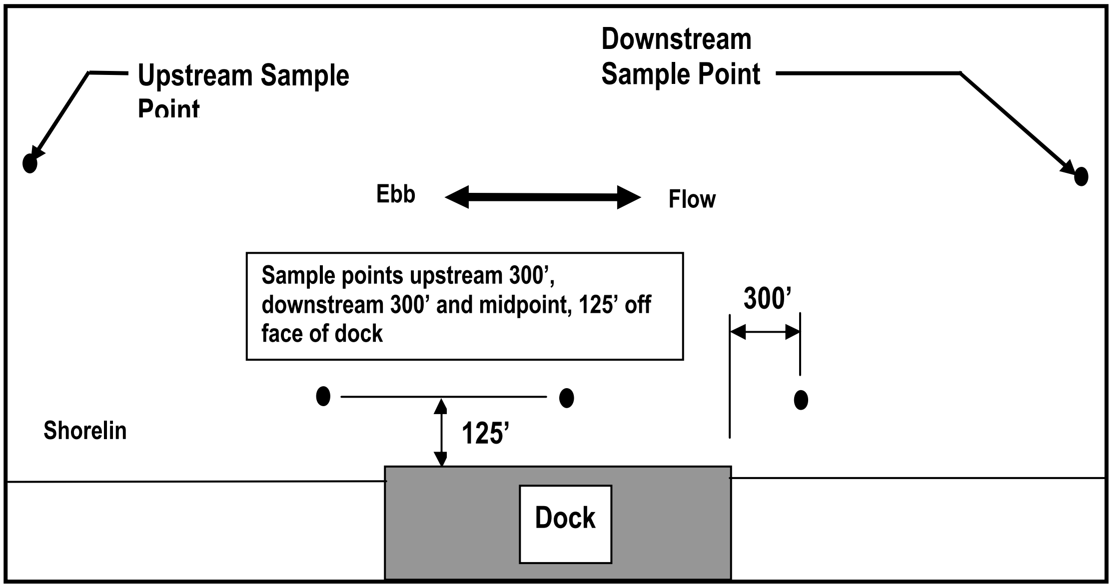



Figure 8: Relative locations of sample points

**System Test Results**

Water quality was the main concern when designing the test protocol, and ultimately the results of five water quality sampling events illustrate the positive effects of the Sediment Suspension system versus frequent dredging. During testing there were elevated levels of turbidity at various times and locations, but this information is all relative to ship activity as well as sampling depth and station. Sampling event #3 was conducted while the sediment suspension system was idle in order to mimic the conditions before the jet system but post dredging. During this event only 2 bottom water samples exceeded 25 Nephelometric Turbidity Units (NTU), which is the water quality criteria standard for turbidity. This shows that the turbidity during operation is somewhat higher than idle periods, but the effects on water quality caused by the sediment suspension system are minimal compared to those caused by dredging.

The first sampling event was performed during active dredging operations, and the results of this event reinforce the benefits of the Sediment Suspension system. All bottom water samples exceeded 25 NTU during sampling event #1, and two of the middle water column stations exceeded 25 NTU. In sampling event #2, only 2 bottom water samples exceeded the 25 NTU criteria, and one middle water column sample exceeded 25 NTU. Event #2 was conducted during the first week of the system's operation. The fourth sampling event showed similar results, but the fifth sampling event showed one extremely elevated level of turbidity as well as other stations with elevated levels of turbidity. This may have been caused by recent ship activity. All samples taken in each event met the water quality standards for dissolved oxygen that cannot fall below 4 mg/L.

The various locations of the sampling points support the data that shows shoaling is not caused at other locations as a result of the system. This was a voiced concern by some, but there are no test results that support this theory.

Three hydrographic surveys were conducted during the course of initial testing just before dredging, immediately following dredging, and six months after dredging. The results of these surveys indicate that after some initial post-dredging shoaling, the system has maintained the targeted project depth of 45 feet below mean low water (MLW).

Port Operations experiences lessened impacts with the system as opposed to the frequent dredging. Dredging impedes Operations from getting ships in at certain times and locations. The Sediment Suspension system does not disturb vessel operations, and during maintenance it only uses up a small portion of the wharf at the location of the jet that is being worked on. Major maintenance is estimated to be needed only about every 10 years.

## Conclusions

A water jet system can be a very attractive alternative to routine berth maintenance dredging. Berths that are less than 250’ wide and are shoaled by slow settling (silt and clay) material are good candidates. The water jet system offers several advantages over conventional dredging. Advantages include no disruptions to vessel operations, reduction in berth maintenance costs, and elimination of disposal area needs. While test results from actual installations indicate no degradation to the water column, environmental regulators are sometimes reluctant to support permitting. Critics may also claim the system increases shoaling in other areas, but this is not supported by test data. The system offers the berth operator a superior way of maintaining safe and consistent project depths at berths.