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UNDERWATER GRADING
A NEW METHOD FOR BERTH MAINTENANCE AT PORT OF PORTLAND

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ABSTRACT

The Port of Portland's maintenance dredging program has experienced significant changes over the last several years. With the elimination of in-water disposal as an option, and some portions of the Portland Harbor being listed as a Superfund-site, maintenance dredging projects have become more complex, labor intensive, and expensive.

Normal sedimentation rates are quite modest at most of the Port's terminals, and the typical maintenance dredging projects have been of a relatively small scale for that reason. Dredging frequencies required for different berths vary from once every two years to more than 10 years apart.

Because the lengthy timelines, high cost and efforts associated with preparation of dredging projects had grown so out of balance with their small scale, the Port sought a better way to address small scale shoaling at its berths.

The method that was selected is the use of an underwater grading beam pulled by a self-propelled barge to flatten high spots, thereby relocating sediments within the footprint of the berthing area. Although simple in nature and not new to the dredging community, use of this methodology at the Port's berths was not without challenges.

This paper provides an overview of the process followed to develop this methodology from the conceptual phase to its implementation. It describes the information used in the regulatory approval process; preparation of the specific equipment used during the grading operation; the grading activities at two of the Port's terminals during July/August 2005 and February 2006; and the data that were collected and analyzed during and after the grading operations, as well as the lessons learned and some conclusions derived from this project.

Keywords: Grading, beam dragging, development, high spots.

INTRODUCTION

The Port of Portland is located in Portland, Oregon, in the area of the confluence of the Columbia and Willamette Rivers, about 160 kilometers (100 miles) from the Pacific Ocean, as shown in Figure 1.

Figure 1. Port of Portland vicinity.

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The Portland Harbor receives approximately 900-1000 vessels per year and roughly 25 million metric tons (27.5 million tons) of waterborne trade, with major cargo streams being grain and mineral bulks and automobiles. The Port of Portland operates four Marine Terminals, three of those located on the Willamette River and one located on the Columbia River.

The sediments found at the Port's berthing areas are relatively coarse-grained with substantial percentages of sand. Columbia River sediments are mostly sand, while the Willamette River sediments are typically more silty. Some of the terminals have a gradual but rather steady influx of new sediment, while some other berths or terminals exhibit either no consistent sedimentation pattern or no long-term net influx.

The maximum draft at most berths of these terminals is 12.2 meters (40 feet). While some berths stay at or below their required depth naturally without any action from the Port, several other berths require dredging in order to maintain the proper depth. Maintenance dredging projects at Port of Portland terminals typically vary in volume from about 1,500 to about 25,000 cubic meters (2,000 to about 35,000 cubic yards), and in frequency from about every two years to as long as 10 years.

Over the last several years, maintenance dredging at the Port of Portland has become more complex and more expensive. Since 1998, in-water disposal options have been eliminated, driving the deposit of all maintenance dredging material from the Port's terminals to upland disposal sites. Permitting requirements have also become more extensive, resulting not only in increased cost, but also in longer timelines. In addition to impacting the overall unit cost, several of these factors apply specifically to the project base cost components, therefore having an even greater impact on the relatively small volume projects.

DEVELOPMENT OF METHOD TO REMOVE LOW VOLUME HIGH SPOTS

Method Selection

Because these increasing complications impeded the Port's ability to perform necessary maintenance dredging, the Port in 2002 initiated a process to develop more efficient and cost-effective methods for berth maintenance.

Several options were explored, with the emphasis on finding a method that could allow for short preparation periods and quick response, enable low set-up and overhead costs, and offer operational flexibility, making it suitable for working at busy marine terminals. The main focus was to find or develop such a method for small volume shoaling situations. A leading thought was that, by developing a supplemental method to better deal with certain localized high spots within a berthing area that limited draft at the terminal, regular maintenance dredging would be needed less frequently. Dredging would still be used to remove larger volumes of sediment, either when significant shoaling occurred in most of the berthing area, or after the berthing area ultimately filled up with newly deposited sediments subsequent to a number of high spot removal actions.

The alternatives with the most promising merits were those in which sediments would not be removed from the river. Total removal of sediments from the river bottom immediately triggers several complications to the process, including use of more heavy equipment; upland disposal and its related issues; and altogether this method automatically reverts to the complexities of dredging that we wanted to avoid for these specific small volume events. Review of technical, environmental, legal and financial factors lead to the conclusion that the most promising approach would be to leave the sediments in situ when possible, as long as they were not concentrated in high spots where they would limit vessel draft.

The alternative deemed most viable was an operation modeled after what is sometimes referred to as "dragging", "sweeping" or "knock-down". Port staff developed a conceptual model, and helpful information was subsequently provided by Donald Cuffel, Principal Environmental Engineer with the Valero Refining Company, which had performed such an operation at its Benicia Crude Oil Dock in the north San Francisco Bay. The Valero team used a steel beam hung from a barge pushed by a tugboat to relocate the sediments within the berthing area. The Environmental Protection Agency, Region 9, also offered pertinent information.

The Port decided to develop a solution based on this method, calling it "Underwater Grading". This name was specifically selected to exemplify the similarities to upland situations, where one wouldn't unnecessarily complicate matters by removing soil from a parcel by truck, if all that was needed was just to restore an even grade. As long as there is no excess of material, but rather just some spots at the wrong elevation, then underwater grading makes good sense, much like grading would be exercised to even out some elevations at an upland parcel.

Realizing that some challenges would lie ahead, and that such simple reasoning would of course not be the only determining factor in successfully implementing this method for berth maintenance, the Port performed further technical analyses.

Regulatory Agency Involvement

During this stage, the Port also initiated communication with the regulatory agencies to keep them informed of what we were looking into and to assure regulators that we were aware of the issues that must be addressed. Although a preliminary legal analysis indicated that no permits would be required, as no material would be removed or newly discharged into waters of the United States, this was certainly somewhat of a grey area, potentially subject to a different opinion. For this reason, and because we wished to work collaboratively with the agencies in the development phase, the Port did apply for, and ultimately received, approval under the regular dredging framework, such as the Army Corps of Engineers 404 Permit, Oregon Division of State Lands Permit, and Oregon Department of Environmental Quality 401 Water Quality Certification.

MERITS OF UNDERWATER GRADING

The proposed method was to grade sediments with a steel beam suspended by cables from a barge with tugboat or from a self-propelled barge. By hanging the beam at the targeted depth, grading to the final depth could be accomplished in the number of runs it took to achieve that depth, without running a risk of grading too deeply.

Main Characteristics of the Proposed Method

- Grading would only take place within the berthing area, applying both to the high spots to be removed as well as to the low areas where the sediments would be deposited.
- Only those berthing areas containing a relatively small volume of high spots, and in which the average depth is substantially deeper than its minimum required depth, would be candidates for underwater grading.
- The beam would remain close to the bottom, to be slightly lifted and lowered only between grading runs.
- If a large volume of sediment had accumulated above grade, and/or if the total berthing area was too close to its required depth, leaving no room to place the graded sediments within the berthing area, then regular maintenance dredging would be the proposed approach.

Advantages of the Method

Shorter Timeframe

Compared to dredging, grading could be accomplished more quickly and with significantly less heavy equipment. No cranes are needed to lift sediment from the river bottom and no barges are needed to transport sediments. Because the Port now owns a self-propelled barge that can be used for grading, the need for contracting is eliminated, contributing to significant savings in both financial terms and in timeline.

Another important advantage of grading, as compared to maintenance dredging, is related to its shortened overall lead time for project preparation. Because of the timings of the typical shoaling season (late spring) due to river flow conditions and the in-water work window (July – October for the Willamette River), it's basically impossible to respond to any new shoaling by dredging within a year.

If a bathymetry survey performed after the spring freshet (June) indicates shoaling that must be dredged, there is not enough time to obtain all the approvals (usually requiring sediment sampling and testing), prepare bid documents, contract, and perform the actual dredging before the end of the work window in October. With August through October being the typical low water period most critical to vessel drafts, decisions about maintenance dredging must be made based on bathymetry that's most likely outdated.

The advantage of grading is that, because of its quick response time, it allows acting on any high spots identified in the June survey before the close of the in-water work window at the end of October, and in some cases even before the low water period makes draft issues critical.

No Disposal Requirements

No disposal activities are required, which eliminates sediment transportation, offloading, dewatering, etc., as well as issues related to permitting, return water, etc.

Fewer Operational Impacts

Because of its small scale and quick mobilization, the operation itself is very flexible. It can operate in relatively small sub-areas of the berthing area, and can be moved in and out rapidly if needed. Because of this, operational impacts to the tenants and terminal users are fewer than those caused by a dredging operation.

Cost Savings

It is expected that the use of underwater grading also reduces the overall need for maintenance dredging. The following factors contribute to some extent to cost savings for grading as compared to maintenance dredging.

- Obviously, in cases where high spots limit the draft at a berth, solving the problem by grading can eliminate the immediate need for a dredging operation.
- For berthing areas that have no net long-term influx of sediments, but instead just contain high spots where sediments are occasionally deposited or redistributed, it would be possible to maintain the berthing area merely by grading whenever the need occurred. Dredging requirements would be totally eliminated for such berthing areas.
- For berthing areas that do have a net long-term influx of sediments, grading could be used to reduce the frequency of dredging. Although potentially the same total volume of sediments would be dredged over time, these results could be obtained by dredging larger volumes on a less frequent basis. Because of the long lead times and the high fixed costs for dredging projects, this would still result in considerable savings for those situations as well.

Fewer Environmental Impacts

Grading also has fewer environmental impacts than dredging. The area targeted for a grading operation is smaller than that for a dredging operation, because it only targets the actual high spots as opposed to dredging, which usually includes overdepth for advanced maintenance.

In addition, any turbidity caused by grading is lower than that caused by dredging. Although both dredging and grading move and therefore disturb sediments, grading activity is limited to the river bottom and is basically just a horizontal movement of sediments. Dredging, on the other hand, moves sediment through the water column. It can create turbidity plumes that extend all the way to the water surface, and that can potentially spread wider horizontally before all sediment settles back to the bottom.

Another fundamental difference between grading and dredging is that grading leaves the sediments in the river system, while dredging removes sediments from the system and, at least in theory, could impact the sediment balance in the system. Although the sediment volumes of maintenance dredging at the Port are extremely low compared to the natural sediment load, grading that may move sediments over a distance of a few hundred feet still leaves it closer to its natural state than would dredging.

Some minor environmental benefits that were identified included reductions in fuel use, emissions, noise, etc. by using less heavy equipment, and the elimination of any return water issues associated with upland disposal.

IMPLEMENTATION OF THE METHOD AND PREPARATION OF THE EQUIPMENT

Implementation

The underwater grading project was developing in concept, but the Port of Portland's available equipment was not ideally suited to implement the operation. Its tugboat and barges were not adequate to handle and stage the grading beam and the multiple winch system.

The Port, which includes a dredging division that owns and operates the 760 millimeter (30 inch) pipeline dredge "Oregon" and support equipment, happened to need some additional support barges at the time underwater grading was being considered. Through the General Service Administration's reutilization program, which tracks surplus equipment within government agencies, the Port was able to purchase several landing barges in San Diego. This provided an opportunity to implement the envisioned underwater grading operation by modifying one of these barges, a Side Loadable Warping Tug (SLWT or Warping Tug), pictured in Figures 2 and 3.

Figure 2. Several government surplus warping tugs, including one with A-frame.

Figure 3. Warping tug lifted from water for transport from San Diego to Portland.

The Port's new warping tug is 25.8 meters (84.5 feet) long and 6.4 meters (21 feet) wide. It features an A-frame boom rated at 9,000 kilograms (20,000 pounds) with double drum motorized winch, and is powered by twin Detroit diesel engines that produce a combined 635 kilowatts (850 horsepower), capable of pushing 113,000 liters (29,900 gallons) per minute of water through each of two 360 degree steerable jet pumps

Equipment Preparation

The warping tug provided a large flat stable platform for winches, turning blocks, and fairleads that could all be located on deck to control the depth and position of a beam hung at a fixed depth under the vessel for performing underwater grading.

To ensure that the grading beam would remain stationary underwater while grading, four fairleads were mounted on doublers to the port and starboard sides of the deck. These four fairleads were positioned at the bow and mid-ship.

Since the beam would have four 25 millimeter (one-inch) wire ropes attached, additional winches (Figure 4) were required. Both a three-drum and a four-drum winch were added to the deck of the warping tug to allow the vessel to travel forward or aft and still maintain grade.

Figure 4. Lifting and positioning winches.

Two winch wires reeve through the forward fairleads for vertical position over the grading beam. The mid-ship fairleads have two 25 millimeter (one-inch) wire ropes attached diagonally to the grading beam. The diagonal wires prevent the beam from swinging forward as the warping tug powers away from the dock in reverse.

If the vessel is pushing the beam forward, the mid-ship wires become the vertical wires for positioning while the forward wires function as the diagonal wires to the grading beam.

The existing winch wire travels through the A-frame and is attached to the center of the grading beam. This allows the grading beam to be removed from the water when not in use, and placed onto the deck of the vessel.

The second wire from the hydraulic winch is connected to a 1350 kilogram (3,000 pound) anchor, so the vessel can be moored in the river when not in use. In the event that additional pulling power is required, the anchor would be deployed; then the barge's own power and the pulling strength of the hydraulic winch would assist with moving the grading beam.

The grading beam itself, shown in Figure 5, is 84 centimeters (33 inches) deep; has 30.5 centimeters (12 inches) flanges; and is 9.15 meters (30 feet) long. To obtain more grading capability, a 91.5 centimeters (3 feet) wide by 1.3 centimeters (½ inches) thick by 9.15 meters (30 feet) long piece of steel was added to the bottom flange.

Figure 5. Grading beam support position.

During the process of transforming the warping tug into a self-propelled barge specifically outfitted for underwater grading, a crew member's suggestion was adopted, and the vessel was subsequently christened the "Epiphany".

INITIAL PORT OF PORTLAND UNDERWATER GRADING EVENTS

The first Port underwater grading project, shown in Figure 6, occurred in July/August 2005 at Terminal 5 Berth 501, involving 300 to 380 cubic meters (400 to 500 cubic yards); at Berth 501 Barge Slip, 150 to 230 cubic meters (200 to 300 cubic yards); and at Berth 503, 230 to 380 cubic meters (300 to 500 cubic yards).

Figure 6. Terminal 5 Berth 503 underwater grading.

The high spots in the Terminal 5 berths were typically situated along the face of the dock, requiring numerous grading passes perpendicular to the berth with the beam pulling built-up sediments out and away from the dock. After the material was pulled away from the dock, the Epiphany ran parallel with the dock to move the sediments to low areas within the berthing prism, filling in low areas with the sediments from the built-up areas.

The Port's second underwater grading project (Figure 7) was performed in February 2006 at the Port's container terminal, Terminal 6, specifically at berths 604 and 605. The quantity of sediments above the minimum required depth of 12.2 meters (40 feet) was about 540 cubic meters (700 cubic yards).

Figure 7. Terminal 6 grading operations.

The Terminal 6 underwater grading operation was performed in the same manner as for Terminal 5, where material was pulled out perpendicular to the dock and then distributed into low areas parallel with the dock. The Epiphany is small enough that it can get in and around the docks and work in very close proximity to container loading and off-loading operations being performed at the same time. This is quite advantageous for terminal operations because berths do not have to be shut down and grading operations do not have to be performed entirely at night or in the short durations between ship calls.

During its initial use at Terminals 5 and 6 in July/August 2005 and February 2006, the Epiphany proved to be extremely valuable, as the Port of Portland would not have been able to restore operating depth within a similar timeframe by use of dredging. In fact, the Port would almost certainly not have been able to restore the operating depths within the respective in-water-work windows for those terminals if dredging had been the only remedy. This is obviously an advantage that goes well beyond the cost savings that were also accomplished in this case, as compared to a dredging approach.

Based on experiences gained from these two projects, it became clear that underwater grading is indeed a technically feasible and sound application for use in the described situations at the Port of Portland. Although the amount of sediments moved per pass or time unit was less than initially anticipated, the Port is currently working on modifications to the vessel winch and fairlead systems in order to reduce the angle that the winches and Epiphany pull on the grading beam. It is anticipated that these measures will improve effectiveness and production rates.

Upland Testing of the Beam Grading Process

Overall, the first underwater grading project in July/August 2005 was successful, but some difficulties were encountered in a few situations where apparently some hard packed sandy sediments proved to be a real challenge to move. Although considerable effort was put into grading those areas, the operations crew felt that no progress was being made in those specific spots, as was confirmed by subsequent hydro-surveys. After loosening that material with a clamshell bucket, grading could be completed.

It was conjectured that the grading beam in that case had been partly sliding on the river bottom or lifting up instead of digging into the bottom. In an effort to gain a better understanding of the process of the beam grading the sediments on the river bottom, the Port performed an upland test after the initial July 2005 underwater grading project. The grading beam was hung from a loader and moved over a sandy parcel with some small humps.

The conclusion from that first upland test, shown in Figures 8 and 9, was that teeth should be added to the leading edge of the bottom flange so that it would provide better cutting action while being moved across the river bottom.

Figure 8. Upland grading test.

Figure 9. Upland grading test.

A subsequent test was performed after those teeth were added, confirming that its ability to cut into the sand had indeed been improved; but it also became apparent that more weight should be added to the beam in order to move more sand. That test showed that, once the beam was positioned at the right angle on the ground, it would quickly pick up sediment and pull a triangular wedge of sediment ahead of it. Once the base of that triangle reached about one to two times the height of the beam, no additional sediment was picked up; instead, the beam just skipped over the surface from that point, retaining the wedge ahead of it.

Based on these upland test and analysis of production data from the Port's first grading event in 2005, it was concluded that the grading beam used by the Port is capable of moving about 0.8 to 1.5 cubic meters (one to two cubic yards) of sediment per single pass, regardless of the distance. Once that volume of sediment is picked up by the beam, it is pulled forward until the beam passes over an area lower than the depth at which it is suspended. At that point, the sediment drops.

Determining the production rate per hour or per day then simply becomes a matter of calculating the number of passes that can be made per time unit. Because the beam appears to pick up sediments rather quickly until the moment it's pulling its maximum capacity, optimizing production is mostly a matter of making multiple short passes that effectively move sediment, rather than making longer passes that will skip most of the way over the river bottom.

Cost Estimates

The daily cost of a 10-hour grading operation, including equipment charges, fuel, labor, etc., is in the order of $3,000. The fixed cost for items like sediment testing, regulatory approval process, bathymetry surveys, set up and mobilization, preparation and maintenance, management, administration and oversight, including staff labor costs, runs very roughly around $100,000 per project.

Compared to a typical maintenance dredging project, both the fixed initial cost component and the incremental unit cost per cubic yard are lower, but the ratio between those two cost components is appreciably different, as well.

Because of its low operational cost, underwater grading's operational costs constitute only a small fraction of the total project cost (about 15-25% for a 5 to 10-day grading operation). For a typical maintenance dredging project at the Port of Portland, the operational cost for dredging, transportation and disposal of sediments is more than 50% of total project cost.

DATA ANALYSIS AND FINDINGS

The process used to verify the displacement of sediments as a result of underwater grading was the same as that used for regular dredging projects: the applicable portion of river bottom is surveyed before the activity and again after the activity. Comparing those two bathymetric surveys provides information about any changes in bottom elevation that may have occurred in the time span between the two surveys.

Although this method is usually suitable for dredging projects, its use to obtain an accurate analysis of the Port's underwater grading operations proved challenging. For grading projects where not only the targeted sediment volume is quite small, but also the layer thickness is less than that of a typical maintenance dredging project, the requirement for survey method accuracy is even more important than usual. Multi-beam surveys were used to provide the highest degree of coverage and accuracy; however, given the nature of this project, the accuracy of this method was approximately plus or minus 15 centimeters (half a foot).

Comparison of the surveys found:

- The very small, localized areas where the underwater grading efforts had been focused were clearly indicated as areas where the biggest changes (drops) in elevation had occurred.
- Some minor elevation changes, for the most part limited to about 15 centimeters (half a foot), plus or minus, had occurred all over the survey area, both inside and outside of the berthing area. These changes appear to have been caused by natural background sediment movement, although they may also be partly attributable to the limitations in survey accuracy, which is about in the same range of 15 centimeters (0.5 foot).

Based on the other project information, such as the exact location where the grading had taken place and the maximum suspension depth of the beam during the operation, the volume of high spot sediment moved through grading activity could still be determined with reasonable accuracy.

On the other hand, it was also clearly understood that the volumes of sediment moved by grading were so small in comparison to the natural sediment movement during the several-week period spanning that grading event, that no method of sediment tracking can exclusively single out the impact of underwater grading.

Because the change of sediment balance (some slight natural sedimentation) within the entire berthing area was larger than the volume graded from the few localized high spots, it was not possible to accurately distinguish sediments moved by grading from sediments that were altogether new to the berthing area.

Turbidity Monitoring

During both underwater grading projects, water quality was monitored in accordance with federal and state permit conditions, both visually and by instruments. Although the applicable permits required only turbidity monitoring, data for parameters including temperature, pH, conductivity, and dissolved oxygen were also collected. Turbidity was the parameter of main interest, and review of the other water quality parameters showed no areas of concern. Therefore, the focus of water quality monitoring during underwater grading activities was and continued to be turbidity. Compliance monitoring, shown in Figure 10, occurred at 3 meters (10 feet) and 6 meters (20 feet) depths at intervals of four hours or less.

Figure 10. Water quality monitoring (foreground) during grading operations (background).

Water quality samples were also taken at times and locations in addition to those dictated by permits. These additional samples were taken to characterize water quality resulting from underwater grading activities in order to gain a better overall understanding of any impacts underwater grading would potentially have on water quality. In general, samples were taken at various depths and locations to capture conditions as close to the operation as possible.

Water quality was monitored during underwater grading activities using a YSI 6600 EDS (extended deployment system) multiparameter water quality sonde and a YSI 650 MDS (multiparameter display system). The sonde was calibrated daily using a two-point calibration procedure. In addition, pressure was also calibrated daily to ensure that depth measurements were accurate. Nearly all measurements were collected from the deck of a sampling vessel, equipped with an outrigger and snatch block which is used to lower the sonde to a specific depth. The monitoring crew consisted of a boat captain and an instrument/data manager. Compliance data was recorded on data sheets for each sampling event, recording time, location, sample depth, sampling event identifier, tide stage, and turbidity. Additional sampling data was collected using the sonde's data logging device. This data was then downloaded, reviewed, and corrected as needed for errors or omissions.

For all monitoring, background turbidity was measured at least 90 meters (300 feet) upriver, well outside of the influence of underwater grading activities. As the Epiphany graded sediment within the berthing area, the sampling vessel would immediately approach and place the water quality sonde as close as possible to the Epiphany. The sampling vessel would then move down-current of the graded area, in search of elevated turbidity levels. Turbidity data was collected at a distance of a few feet from the grading event to 90 meters (300 feet) from the grading beam at various depths throughout the water column, ranging from 0.3 to 13.1 meters (1 to 43 feet) below the water surface. The sonde was programmed to record a turbidity measurement every 20 seconds with a refresh rate of 0.5 seconds.

For one day during underwater grading activities, the 650 MDS was connected to a Trimble Geo XT GPS unit to record the geographic coordinates associated with each sample. In order to determine the relative proximity of the sampling vessel to the grading beam, GPS coordinates that were also recorded on the Epiphany were compared to the coordinates associated with each water quality sample.

A total of 425 water quality samples (summarized in Table 1) were collected in the Columbia and Willamette Rivers during the two separate underwater grading events previously described.

Table 1. Turbidity values during underwater grading activities.

	Background	**Downstream**
T5 (none of 10 were ≥ 5 NTU above background)	3.4-7.6	3.3-7.7
T6 (none of 13 were ≥ 5 NTU above background)	5.2-8.0	5.6-9.0
Research data (41 of 402 samples were ≥ 5 NTU above background)	3.3-9.4	1.5-29.5

Background turbidity levels in the Willamette River (July/August activity) ranged from 3.3 to 9.4 Nepholometric Turbidity Units (NTU), while turbidity measured down-gradient of grading activities ranged from 1.5 to 29.5 NTU. Columbia River (February 2006 activity) background levels were between 5.2 and 8.0 NTU, while turbidity levels down-gradient of the grading operations ranged from 3.3 to 9.0 NTU. Of the 425 samples collected at various depths in both the Columbia and Willamette Rivers, 96% were within 5 (NTU) of measured background levels, including samples collected near the river bottom and within a few feet of the grading beam. As the grading beam was only deployed for a few minutes at a time, elevated turbidity levels were rarely seen.

Graded material consists of medium to coarse grain sand in the Columbia River and sandy silt in the Willamette River. Turbidity levels seen in both types of material were quite low. In fact, higher turbidity levels that often result from the movement of siltier material were not observed during underwater grading activities.

Grading operations were halted when exceedances of the water quality standards occurred. For this activity, permits allow a 10-percent increase over background levels, which is quite low especially considering backgrounds ranged from 3.3 to 9.4 NTU's. This results in an allowable increase of 0.3 NTU's to less than 1 NTU for all grading operations undertaken.

In only one case was a visual plume observed. A total of three exceedances occurred during these grading activities. During one exceedance, a tugboat was operating simultaneously in the berthing area during grading operations and likely caused or largely contributed to elevated turbidity levels. During the other two exceedances, simultaneous construction activities in the berthing area at Terminal 6 may have contributed to the elevated readings. In all cases, the elevated turbidity levels resumed to background after the temporary stoppage of grading operations.

The data summarized above show that turbidity levels associated with underwater grading activities were never in a range that would be harmful to any local sensitive fish species. As stated, over 96% of all the samples taken were within 5 NTUs of background, even when monitoring within 3 meters (10 feet) of the grading beam. Probably in part due to the intermittent nature of grading, it was difficult to find elevated turbidity levels. When levels higher than background were observed, they tended to be close to the bottom of the river, and dissipated very quickly.

CONCLUSIONS

In terms of conclusions and lessons learned from the recent underwater grading experiences at the Port of Portland, the overall impression is that this technique has proven valuable as a supplemental method for maintaining the Port's berthing areas. For the most part, the method worked as planned and anticipated.

Operational Efficiencies

The Port is working to further improve the effectiveness of this method in locations where sandy sediments are hard packed, and in locations where high spots are present immediately adjacent to dock structures.

The simplicity of the method provides for quick and effective response, with minimal tenant impacts. This quick response time is a valuable benefit that is not typically provided with a dredging approach.

Cost Effectiveness

In those situations where it is most applicable, use of this method as an alternative to dredging can result in significant cost savings.

Environmental Benefits

Based on environmental criteria, the underwater grading method utilized by the Port of Portland compares favorably to maintenance dredging.

This method offers excellent depth and location control because of its application in the berthing area adjacent to the dock, and because the grading beam is set to the specified target depth.

Any observed turbidity increases were very small, whether measured as percentage points or as NTU levels. It was actually difficult to identify any turbidity increases related to the underwater grading activity, since any observed increases were limited to the lower portion of the water column near the river bottom, and to the immediate vicinity of the grading operation.

For the types of situations in which the Port of Portland proposes to use this method, sediment displacement from grading will be minimal when compared to natural sediment movement.

Since this method does not newly deposit any sediments in-water, the relevance of any contamination that may or may not be present in the sediments should be considered differently in relationship to underwater grading than to dredging with in-water disposal. The environmental effects of any contaminated sediments being located in the high spot location within a berthing area – versus, for example, in a location 30 meters (100 feet) away – are in almost all cases negligible or zero. If anything, since this all plays out within the berthing area, those sediments if accumulated above required grade would be more subject to re-suspension than after being graded into a lower area nearby.

To some extent, the possibility that any existing contaminants might be re-suspended due to grading remains an unresolved issue. Underwater grading does, of course, disturb sediments by moving them a short distance, although disturbances are limited to the lower water column, whereas in clamshell dredging, the bucket continuously moves through the entire water column, thus potentially increasing the rate of re-suspension. Because of this issue, the Port of Portland has initially proposed to perform grading only in situations where no contaminated sediments are present.

There is much to be said for using sediment characterization requirements specific to potential underwater grading impacts, rather than just copying requirements from dredging approval evaluations. In the described situations where the Port of Portland sees value and applicability in the underwater grading method, a less onerous but more specific requirement for sediment characterization would facilitate appropriate use of this method. Method-specific characterization requirements would result not only in increased service and quality for marine users, but also in the increased relevance of sediment characterization results. Environmental benefits would be supplemented by cost savings and significant shortening of preparation timeframes for berth maintenance projects.