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WARD COVE SEDIMENT REMEDIATION PROJECT REVISITED: LONG-TERM SUCCESS OF THIN-LAYER PLACEMENT REMEDY

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ABSTRACT

In 2001, approximately 11 hectares (27 acres) of the sediment in Ward Cove, Alaska, was amended with 15 cm (6-in.) or more of clean sand. The amendment was placed over very soft, organic-rich sediments at bed surface depths from –3 to –36.5 m (–10 to –120 ft) mean lower low water. There was some uncertainty as to whether the bed surface could support 6-in. of sand based on sediment bearing capacity calculations derived from *in situ* vane shear and triaxial laboratory testing. However, based on performance verification measures and acceptance criteria evaluated during construction, all proposed thin-layer placement (TLP) areas were satisfactorily amended with greater than 40 percent by dry weight of sand in the top 10 cm (4 in.) of the sediment surface. Reduction in organic carbon content through fine sand amendment was predicted to reduce toxicity in the surface sediments and enhance recolonization of the benthic infaunal community. The short-term success of the TLP was attributable to a number of aspects of the remedial operation. First, the derrick barge was of appropriate size to move into tight areas within the area of concern, and it supported use of a modified 6-cubic meter (8-cubic yard) bucket that was demonstrated to place material well across the range of bottom conditions and depths for the remediation project. In addition, the WINOPS system was a key factor in positioning the dredge and the individual buckets in the next adjacent TLP area to ensure that all areas were uniformly covered with minimal overlap. Finally, the TLP material was of appropriate grain size distribution to permit uniform spreading and placement across each acceptance area, without substantive impacts to water quality. The long-term effectiveness of the remedial activities was evaluated 3 years after TLP, in 2004. Results of the monitoring event showed that conditions in the amended areas had reduced toxicity and increased the abundance and diversity of benthic communities. It was concluded that the amendment was successful in remediating the native sediments and that benthic communities would continue to develop in the remediated areas in the future. The next monitoring event will be conducted in 2007.

Key Words: Capping, enhanced natural recovery, performance verification, monitoring

INTRODUCTION

The investigation of the Marine Operable Unit (OU) of the former Ketchikan Pulp Company (KPC) site and the design and implementation of a cleanup alternative were initiated under a Clean Water Act Consent Decree (September 1995), between the U.S. Environmental Protection Agency (EPA) and KPC. The remediation work was completed under a Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Consent Decree (November 2000) between EPA, KPC, and Gateway Forest Products. Remedial activities in Ward Cove included constructing a dike for dewatering dredged material, removing underwater logs and wood debris in areas to be dredged, dredging sediments to improve navigation, placing a thin-layer cap of 15-30 cm (6-12 in.) of sand over approximately 11 hectares (27 acres) of the Marine OU (including approximately 0.8 hectares 2 acres of area dredged), and disposing of log wood debris and dredged material in the dewatering area (Foster Wheeler Environmental 2001). Remedial activities were conducted from November 2000 to March 2001. Disposal of dredged material was completed in June 2001.

This paper provides a summary of the Ward Cove sediment remediation project with emphasis on the 2000/2001 thin-layer placement (TLP) remedy, including performance verification and acceptance criteria evaluated during construction (Foster Wheeler Environmental 2001b) and the results of the 2004 long-term monitoring event

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(Exponent 2005). This paper follows one prepared for the Western Dredging Association's *Journal of Dredging Engineering* titled, "Engineering Case Study – Ward Cove Sediment Remediation Project, Ketchikan, Alaska" (Herrenkohl et al. 2003). Historical project information and construction activities of the project described in Herrenkohl et al. (2003) are summarized or in some cases, repeated in this paper.

PROJECT SITE AND HISTORY

Ward Cove is approximately 1.6 km (1 mile) long with a maximum width of approximately 0.8 km (1/2 mile). The shoreline of the cove consists primarily of basalt rock and is relatively steep. More than two-thirds of Ward Cove is deeper than 30 m (~100 ft). Sediments in the cove are predominantly subtidal with only a small fraction found in the intertidal zone (EPA 2000).

Located on the shoreline of Ward Cove, the former KPC mill operated continuously from 1954 until 1997, processing logs into lumber, pulp, and hog fuel. The principal product of the KPC mill was dissolving-grade sulfite pulp. When pulp production began in 1954, effluent from the mill, including spent cooking acid (magnesium bisulfite) and bleaching agent (chlorine caustic), was discharged directly into Ward Cove. After 1971, when federal and state environmental regulations went into effect, effluent was treated in a wastewater treatment plant located at the mill. This treatment resulted in a substantial reduction in the release of spent sulfite liquor, suspended and settleable solids, and oxygen-consuming substances in the cove (EPA 2000).

The former KPC site is divided into two administrative units: the Marine OU and the Uplands OU. The boundary between the two OUs is the mean higher high water line. The response action described in the March 29, 2000, record of decision (ROD) addresses the Marine OU only. The Marine OU consists of approximately 100 hectares (250 acres) in Ward Cove (Figure 1).

Numerous environmental studies of Ward Cove have been conducted to evaluate the potential environmental effects associated with the historical discharges from the KPC facility (EPA 1975, Jones & Stokes and Kinnetic 1989, EVS 1992, ENSR 1995, E&E 1998, Exponent 1999, Exponent and Hartman 2000a,b). Historical studies focused on water quality impacts and sediment chemistry and toxicity studies. These studies documented a variety of potentially adverse conditions and effects in the water column and sediments in Ward Cove. Elevated levels of chemicals of potential concern (CoPCs) and sediment toxicity were found nearest the mill and a cannery that operates on the southern shoreline.

REMEDIATION OVERVIEW

Comprehensive studies of the Marine OU were conducted by KPC in 1996 and 1997, with EPA oversight, to evaluate the extent to which sediments in Ward Cove may pose risks to humans and to the environment and potentially warrant remediation (Exponent 1999). Surface and subsurface sediment samples were collected at various locations throughout Ward Cove and at two locations in Moser Bay (as a reference area). The goal of this investigation was to analyze both vertical and horizontal presence and concentrations of CoPCs, and to further determine the relationship between the CoPCs and the KPC mill site. The sediment data from Ward Cove indicated that sediments were impacted by historical releases from the KPC site, and toxicity tests demonstrated that the sediments were toxic to some marine animals that live in the sediments. The chemicals of concern (CoCs) identified for sediment toxicity were ammonia, sulfide, and 4-methylphenol. However, based on the results of the risk assessment, sediments in Ward Cove did not pose unacceptable risk to humans or to wildlife (e.g., marine birds and mammals).

Extensive investigations were also completed at the Uplands OU. As part of those investigations, the potential for releases of contaminants from the upland site to Ward Cove sediments was investigated. Soil removal actions have also been completed at the site. Based on findings of the environmental investigations for the Marine and Uplands OUs, EPA concluded in the ROD that no further physical actions were necessary to control contaminant releases from the upland site to the Cove (EPA 2000).

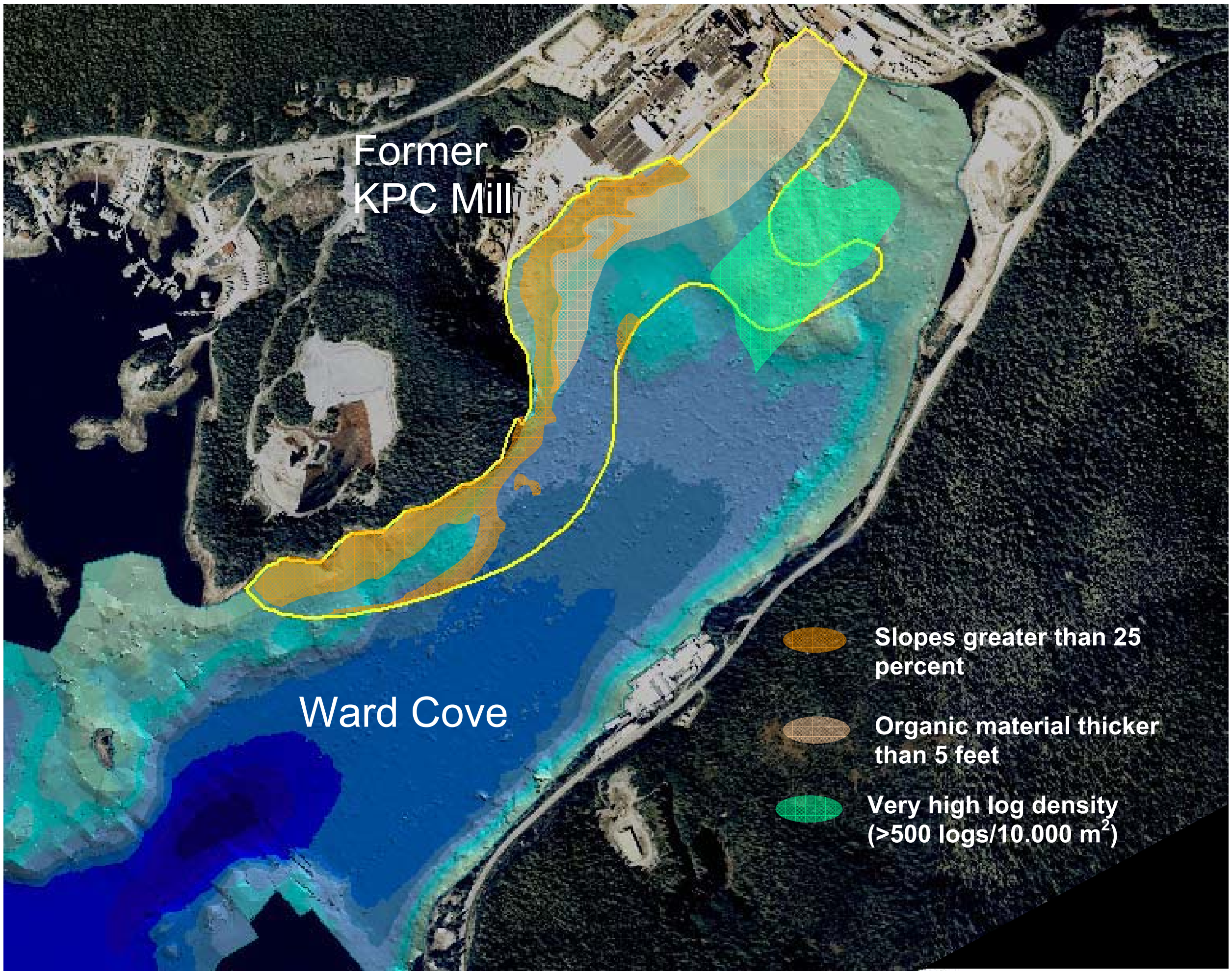

Figure 1. Ketchikan Pulp Company, area of concern (from Exponent 1999).

Area of Concern

In May 1999, KPC completed a detailed technical studies report (DTSR) (Exponent 1999) of the contaminated sediments in Ward Cove. The DTSR included a remedial investigation, which documented the nature and extent of sediment contamination, and a feasibility study, which evaluated remedial action alternatives. The DTSR identified an 32-hectare (80-acre) area of concern (AOC) where, based on human health and ecological risk assessments, remedial action was warranted as a result of sediment contamination posing a risk to benthic organisms (Figure 1). Sediments in the AOC were found to contain chemicals (4-methyphenol, sulfide, ammonia) produced during the *in situ* biodegradation of organic material released by mill operations at concentrations toxic to benthic biota.

Subsequent to the DTSR, additional remedial design sampling was conducted in Ward Cove in September and October 1999. The results of the design sampling are presented in the cruise and data report (Exponent and Hartman 2000a). Information from remedial design sampling was used to refine the boundaries of the AOC as documented in Exponent and Hartman (2000a). The data from this sampling and the data in the DTSR were used to perform design calculations and computer modeling for a design analysis report (DAR) (Exponent and Hartman 2000b). The DAR was prepared as part of the remedial design phase for implementation of the remedial action set forth in the ROD for the Marine OU (EPA 2000).

Remedial Action Objectives and Scope

The Ward Cove remedial action objectives (Exponent 1999) were to:

- Reduce toxicity of surface sediments; and
- Enhance recolonization of surface sediments to support a healthy marine benthic infaunal community with multiple taxonomic groups.

The selected remedy for contaminated sediments in Ward Cove consisted of natural recovery, dredging, and TLP. Natural recovery was selected for those portions of the AOC where there were thick deposits of soft surface sediments (with high moisture content and low bearing strength), water depths in excess of 36.5 m (120 ft), steep slopes, or a high density of logs. Overall plan views of the remedial action acceptance sections are shown in Figures 2a and 2b.

The selected remedy included the following planned elements:

Log Removal—Prior to dredging, removal of sunken logs in the area to be dredged and removal of logs from the bottom surface of the shallow water approach (barge access channel).

Navigation Dredging—Dredging material from approximately 1.6 hectares (4 acres) of sub-bottom to accommodate reasonably anticipated future navigational needs, and because an isolation cap could not be placed in these areas without constraining current and potential future navigation needs.

Thin-Layer Placement—Placement of a 15-30 cm (6-12 in.) thin layer of clean sandy material over the problem sediments. The TLP was estimated in the DAR to be practical for approximately 11 hectares (27 acres).

Mounding—Where TLP was found to be not practical because of low bearing capacity, mounds of clean material would be placed. The mounding areas represented a minimum of 0.4 hectare (1 acre), with the potential to place mounds across as much as 8 hectares (20 acres) should the TLP be found to be not effective.

Natural Recovery—Natural recovery (no construction action) in areas where neither TLP nor mounding was considered feasible (approximately 20 hectares [50 acres] of Marine OU).

Prior to remediation in 2000/2001, no sediment remediation activities had occurred in Ward Cove. Some maintenance dredging operations had been conducted previously near the main dock and mill log lift operation in accordance with U.S. Army Corps of Engineers permits.

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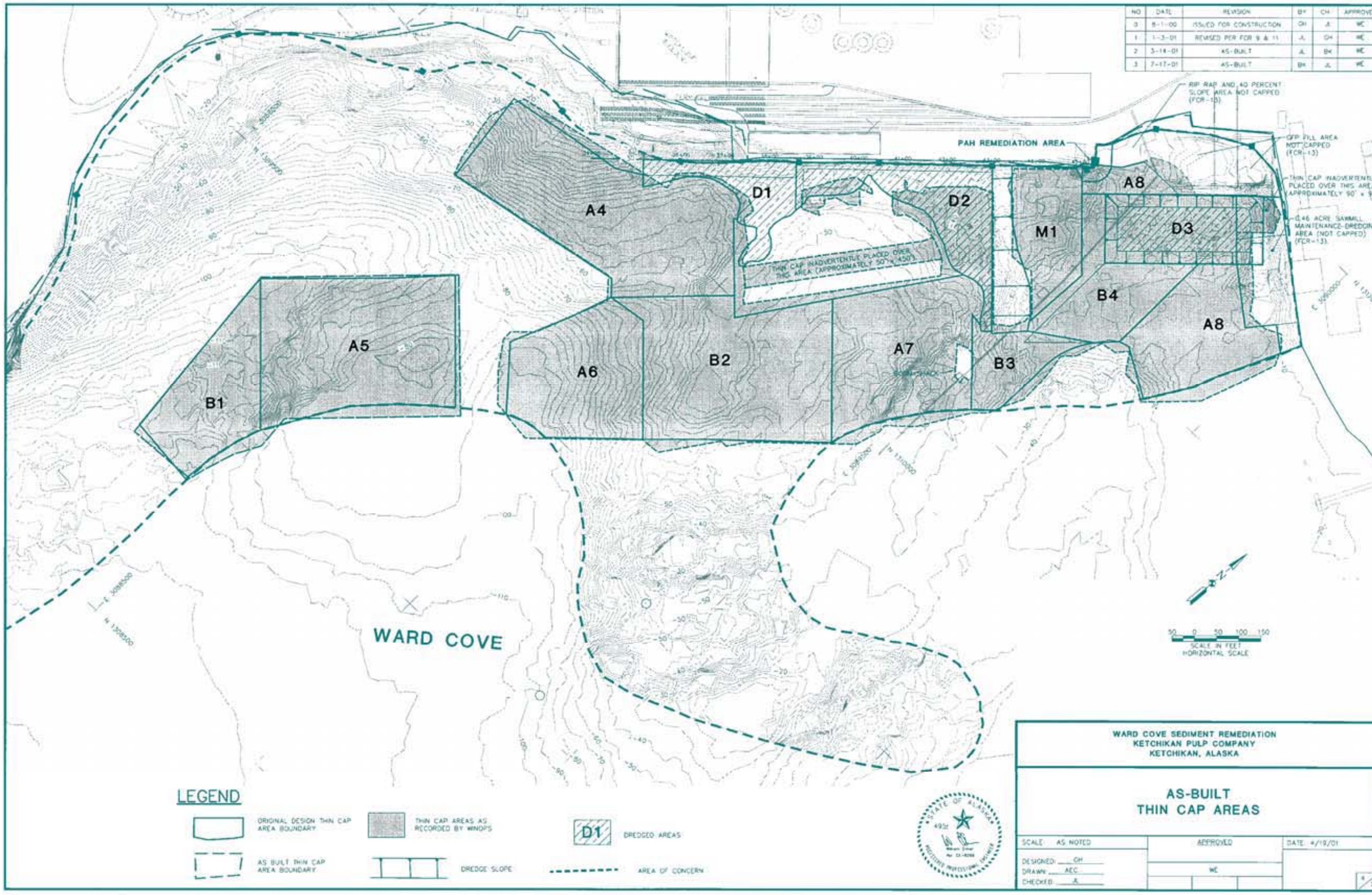

Figure 2a. As-built thin cap and dredging areas (from Foster Wheeler Environmental 2001b).

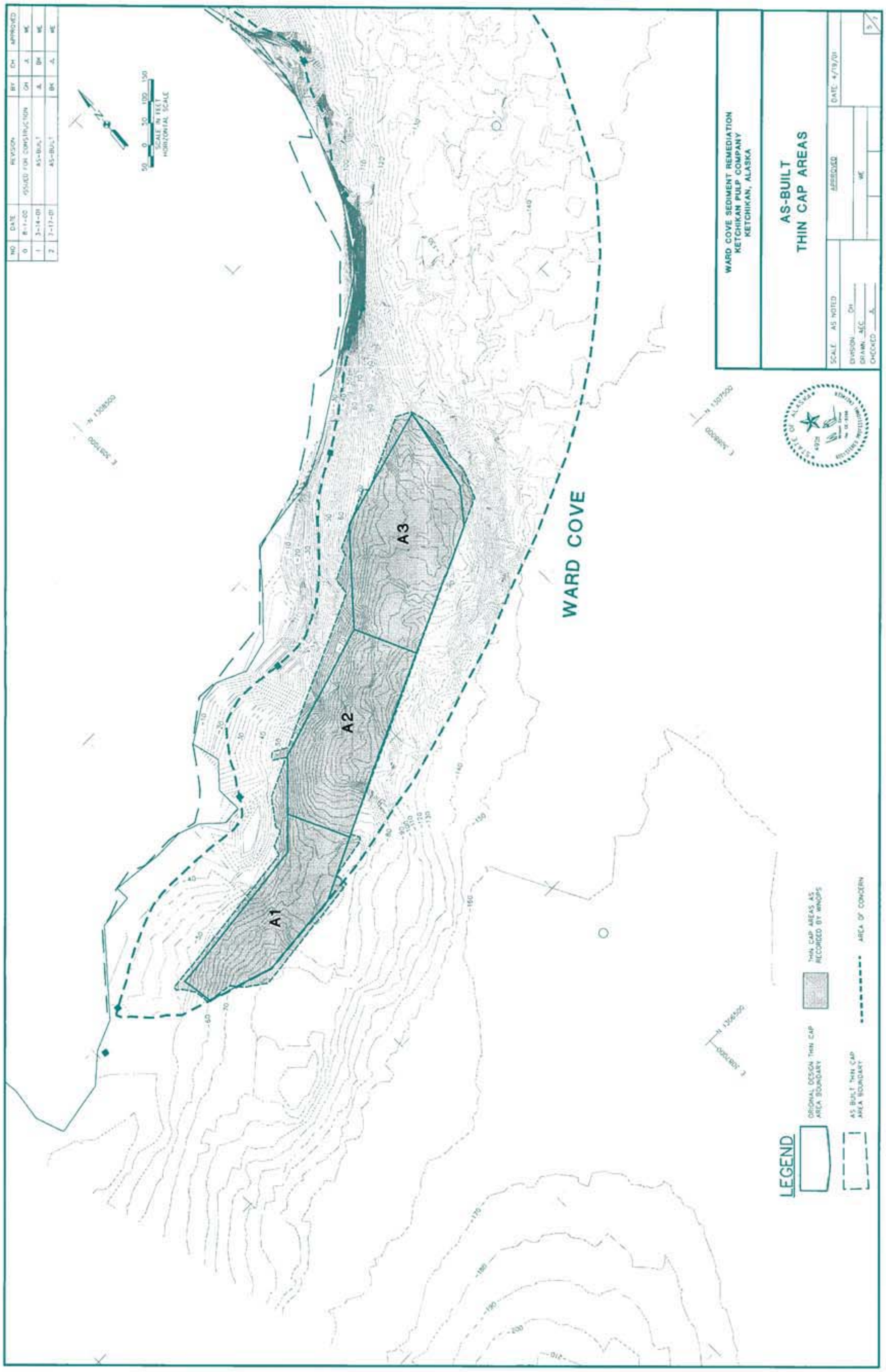

Figure 2b. As-built thin cap and dredging areas (from Foster Wheeler Environmental 2001b).

TLP Challenges

Low Bearing-Strength Sediments

The ability of the organic material to support the weight of 15 to 30 cm (6–12 in.) of sand was evaluated using foundation bearing capacity equations described in Holtz and Kovacs (1981). These equations are used to calculate allowable bearing capacity of foundations for all types of facilities. The same equations were applied to evaluate sand cap support at the New York Mud Dump site (Rollings and Rollings 1998a,b), the McCormick and Baxter site in California (USACE 2000), and the Puget Sound Naval Shipyard confined aquatic site and head of the Thea Foss Waterway in Puget Sound (Foster Wheeler Environmental 2001a, Tetra Tech FW 2003).

For fine-grained sediments like those at Ward Cove, the bearing capacity depends on the short-term shear strength of the sediment (referred to as the undrained strength). *In situ* vane shear testing was performed at nine locations within the AOC to estimate bearing strength of the sediments (Exponent and Hartman 2000a). In addition, representative undisturbed cores were collected from selected locations and further evaluated for bearing strength by completing the unconsolidated undrained triaxial test in the laboratory.

For this project, a minimum shear strength required to support 15-cm (6-in.) of sand was derived. The minimum shear strength was then compared with the shear measurements taken at specific locations in Ward Cove to determine where the sediment will support TLP and where it will not. The minimum undrained shear strength needed to support 15-cm (6-in.) of sand was evaluated to be 58.6 kilograms per square meter (kg/m^2) or 12 pounds per square foot (psf). This value was based on static bearing capacity analysis with a factor of safety of 2.0. This minimum factor of safety was recommended to account for uneven distribution of sand and the low dynamic impact effects during placement. This gave an ultimate factor of safety of 1.0 for those discrete areas where the sand may be 30 cm (12 in.) thick.

The bearing strength measured in the upper 0.75 to 1.5 m (2.5 to 5.0 ft) of sediment in representative locations of the AOC ranged from < 15 to 73 kg/m^2 (< 3 to 15 psf). Overplacement of a sand layer can create failure of TLP on the surface of sediment with low shear strength. Placement of a layer thicker than 15 cm (6 in.) will also result in a factor of safety less than 1.0 for a shear strength of 29 kg/m^2 (6 psf). A 30-cm (12-in.) thick layer will have an estimated factor of safety of 0.5 for a shear strength of 29 kg/m^2 (6 psf). In design terms, this would lead one to expect that the surface sediment would fail to support the TLP. For this project, sand was being added to sediments to amend, not isolate, *in situ* sediment. Some displacement of existing sediments was expected and allowed.

Slope Stability Analysis

The minimum factor of safety for a given slope is the lowest factor of safety of all potential surfaces to create sliding. For the case of 15–30 cm (6–12 in.) of sand placed over soft organic material, two types of sliding surfaces were considered: shallow sliding surfaces in the cover sand, and deeper sliding surfaces through both the sand and underlying organic material.

Static stability of sand on slopes can be analyzed by the "infinite slope" equations, which are based on the assumption of a long slope with constant sand thickness. In this case, the assumption was made that the underlying material was stronger than the sand. For a silty fine sand and a factor of safety of 1.5, the maximum slope would be approximately 40 percent. This value is consistent with construction experience for underwater placement of sand slopes (Exponent and Hartman 2000b).

Sand placed underwater has a natural angle of repose between 30 and 50 percent (i.e.,slopes of 3H:1V to 2H:1V) depending on the particle size of the material and the method of placement. For waterfront construction on firm sediment, coarse sand and gravel (1.0 to > 4 mm) can be placed on 50 percent slopes.

For the Ward Cove remediation project, the material to be placed on the fine organic sediment could not be gravel and coarse sand. This grain size for TLP material would tend to sink into the sediment and would not provide quality benthic habitat. Therefore, the TLP material was required to be fine-to-medium sand with minimal fines. Because of the very soft existing sediments and steep slopes in Ward Cove, the TLP material must be released slowly so that the settling velocity is low and bed impact is minimized.

Slope stability factors of safety were calculated for different slopes, various thicknesses of organic material, and different shear strengths of organic material (Exponent 1999, Exponent and Hartman 2000b, Herrenkohl et al. 2003). It was assumed that the sand after placement would be 15 cm (6 in.) thick. The slope criteria determined for the Ward Cove site were as follows:

- The maximum sediment slope for TLP of a silty fine sand without rip-rap protection was 40 percent.
- Where the sediment slope was between 10 and 40 percent, the stability of 15–30 cm (6–12 in.) of sand depends on the shear strength of the organic material and the thickness of the organic matter.
- For slopes less than 10 percent, the TLP stability was controlled by the bearing capacity of the organic material.

THIN-LAYER PLACEMENT

The largest in-water work activity accomplished as part of the Ward Cove remediation project was TLP of approximately 11 hectares (27 acres) of subtidal area in the AOC (including areas outside the designated placement areas). TLP was accomplished using the *Miller 205* derrick barge with a 6-m^3 (8-cy) Cable Arm rehandling bucket (Figure 3). EPA-approved TLP materials, including both fine-medium clean sand and coarse sand as defined by the contract documents, were delivered to the site on 10,000-ton deck barges from the Construction Aggregates, Ltd., quarry near Victoria, British Columbia. The TLP material was offloaded using an unloader and conveyor system to the sand stockpiling area located on the eastern shoreline of Ward Cove, across from the mill. Material to be placed in the design test areas and acceptance areas was placed on one of two 1,150-m^3 (1,500-cy) sealed material deck barges and, when full, transported by tug to be rafted alongside the derrick barge.

Figure 3. Thin-layer placement in Ward Cove.

In accordance with the contract plans, TLP design tests were conducted prior to production TLP to develop a placement methodology that would best meet the performance requirements of the performance standard verification plan (PSVP) (Exponent and Hartman 2000c). The contractor was required to first attempt TLP with a mechanical dredge equipped with a clamshell bucket. Nominal 1/8-hectare (1/3-acre) design test areas were delineated in each of the acceptance areas and agreed to by all parties. These approved design test areas were entered into the WINOPS guidance system with a TLP pattern developed by the subcontractor that would provide the operator with a plan showing all required individual bucket "swaths." Each bucket discharge would provide for a minimum 15-cm (6-in.) thick placement over the swath. After the first day's trial TLP, it was determined that the bucket would require modification by welding baffle plates inside the bucket to provide for a consistent grab volume (4.2 m^3 or 5.5 cy). It was also determined that the bucket opening chains were not long enough to provide the required force necessary to open the bucket when full of wet capping material. Based on input from the bucket manufacturer, Cable Arm, Inc., the opening chains were lengthened. These modifications served to provide a consistent means of acquiring a uniform volume of approximately 4.2 m^3 (5.5 cy) per bucket grab. The WINOPS system was used by the contractor to develop a TLP plan that incorporated the operational parameters of 7.3-m (24-ft) barge sets, with six to nine bucket swaths per set, and individual placement discharge swaths of 11.6 by 2.4 m (38 by 8 ft). The plan, displayed on two onboard WINOPS monitors, provided the operator and deck engineer the precise locations of the derrick barge position in order to advance and continue TLP, adjacent to a completed area, and within the design test/acceptance area.

The above described TLP method was tested in design test areas A8, B3, A7, B2, A4, A6, and M1, respectively (refer to Figures 2a and 2b). The TLP method, which provided a 15-cm (6-in.) thick layer of sand, was successful in meeting the PSVP standard in all areas tested. EPA then granted approval to forego additional 1/8-hectare (1/3-acre) TLP tests and proceed with production TLP. No use of the proposed additional 7.5 cm (3-in.) TLP was necessary, nor was mounding required as specified in the DAR. Use of the 7.7-m^3 (10-cy) skip box proposed for the alternative TLP method was not required because the original clamshell method proved successful for all of the 15-cm (6-in.) TLP effort.

Once design tests in areas A8, B3, A7, B2, A4, A6, and M1 were completed and found to be successful, TLP operations shifted into production mode. TLP was accomplished over 15 acceptance areas (Foster Wheeler Environmental 2001b, Herrenkohl et al. 2003).

To confirm that all planned areas were covered successfully, confirmatory performance standard verification sampling was conducted in acceptance areas by means of modified 0.1-m^2 van Veen shallow grab sampler, diver push cores, and underwater video. The performance standard verification sampling showed the TLP to be successful. All areas were satisfactorily amended with greater than 40 percent by dry weight of sand in the top 10 cm (4 in.) of the sediment surface.

In total, approximately 17,800 m^3 (23,300 cy) of sand was uniformly distributed over the acceptance areas requiring enhanced natural recovery. Of this volume, approximately 1,500 m^3 (2,000 cy) was the coarser material (7.5-cm or 3-in. minus), which was placed uniformly over acceptance areas D3 and B4 to provide additional scour protection due to anticipated shallow draft vessel usage (Figures 2a and 2b).

LONG-TERM MONITORING RESULTS

The effectiveness of the remedial activities completed for the site will be assessed by implementation of the long-term monitoring plan (Exponent 2001) in compliance with the CERCLA Consent Decree (November 2000). The monitoring program was designed to evaluate three major indicators of sediment quality in Ward Cove, specifically sediment chemistry, sediment toxicity, and benthic macroinvertebrate communities. The first year of monitoring was completed in 2004 (Exponent 2005). Surface sediment samples were collected at 37 station locations within the 32-hectare (80-acre) AOC and at 10 stations from two reference areas outside the AOC but within Ward Cove. Within the AOC, samples were collected from representative locations from both enhanced natural recovery areas (TLP) and natural recovery areas. The monitoring results were very favorable. Sediment concentrations of CoCs in TLP areas were generally below site-specific sediment quality values. Amphipod survival, a measure of sediment toxicity, was very high at most stations sampled in the TLP areas. The diversity and abundance of major benthic macroinvertebrate taxa have significantly increased in the remediated portions of Ward Cove when compared to pre-remediation data and reference locations. The most notable increases in abundances were found for molluscs and polychaetes.

EFFECTIVENESS OF THIN-LAYER PLACEMENT

The results of the 2004 monitoring study, the first study to be conducted since remediation was completed in 2001, indicate TLP was successful in eliminating sediment toxicity and stimulating the recolonization of benthic macroinvertebrate species in once impacted sediments. The success of TLP is attributable to a number of aspects of the placement operation. First, the derrick barge was of appropriate size to move into tight areas along the Marine OU boundary, and it supported use of a modified 6-m^3 (8-cy) bucket that was demonstrated to place material well across the range of bottom conditions and depths for the remediation project. In addition, the WINOPS system was a key factor in creating real-time knowledge of positioning the barge and the individual buckets to ensure that all areas were enhanced with 15- to 30-cm (6- to 12-in.) of sand, with minimal overlap, while providing the most uniform coverage possible. Finally, the imported sand material also contributed to the success of the TLP. The capping material was of appropriate grain size distribution and specific weight to permit uniform spreading and placement across the capping acceptance areas without substantive impacts to water quality.

The next monitoring study of Ward Cove is planned for 2007. If the 2007 monitoring results (sediment chemistry, sediment toxicity tests, and benthic community analyses) are consistent with or better than the 2004 data, monitoring of benthic communities, and potentially sediment chemistry and toxicity, in the TLP areas may be discontinued (Exponent 2005).

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