

17 August 1994

MEMORANDUM FOR Chief, CENPP-OP-NW, ATTN: Mr. Steve Chesser

SUBJECT: Depoe Bay Sediment Evaluation

1. In February 1994, an environmental evaluation of the sediment from Depoe Bay was conducted following MPRSA guidelines. The combined results from three bulk sediment studies, and an elutriate study are sufficient to show that Depot Bay sediment is acceptable for in-water disposal and that no unacceptable, adverse, contaminant-related impacts to the aquatic environment will result from such disposal. This conclusion is based on a tiered testing evaluation of the sediment using guidelines developed to implement the MPRSA. In-water disposal is not expected to violate State water quality standards outside of the mixing zone.

2. If you have questions regarding this study, please contact Mr. Jim Britton, CENPP-PE-HR, extension 6471.

Encl

DALE S. MAZAR, P.E.
Acting Chief, Hydraulics and
Hydrology Branch

CEN/FILES
CENPP-PE-T

Jan 8/92

RETURN TO:

CENPP-PE-H

COMPLETION

MAZAR *8/92*

CENPP-PE-H *8/92*

CASSIDY *8/92*

CENPP-PE-H *8/92*

JB BRITTON

CENPP-PE-HR

6471/LN

18 Aug 94

Depoe Bay Sediment Evaluation

Abstract

The combined results from three bulk sediment studies and an elutriate study are sufficient to show that Depoe Bay sediment is acceptable for in-water disposal and that no unacceptable, adverse, contaminant-related impacts to the aquatic environment will result from such disposal. This conclusion is based on a tiered testing evaluation of the sediment using guidelines developed to implement the MPRSA. In-water disposal is not expected to violate State water quality standards outside of the mixing zone.

Introduction

1. Depoe Bay is a very small inlet 100 miles south of the mouth of the Columbia River (Figure 1). The bay is fed by two small streams called North and South Depoe Bay Creek. A check dam is located a few hundred feet upstream of the entry of South Depoe Creek into the bay. The check dam helps to collect sediment before it enters the bay. Water and sediment quality is more affected by tidal movement of water into and out of the bay than streamflows in the two creeks (1).

2. The authorized project includes two breakwaters that lie north and south of the rocky entrance. The entrance channel is 8 feet deep and 50 feet wide. The inner basin is 8 feet deep, 750 feet long and 390 feet wide (2).

3. Depoe Bay is dredged every three to five years, usually by pipeline. Over the last nine years about 15,500 cubic yards (cy) have been dredged from the harbor - 1,500 cy in 1987 and 14,000 in 1989. Dredging takes place between June and September 15th. Most of the bay sediment is removed by pipeline and pumped over the bluff, separating the bay from the ocean, into the rocky surf zone about 200 feet south of the entrance channel (Figure 1). Sediment removed by clamshell or backhoe is trucked to an upland disposal site (2). In the past, sediment trapped by the catch dam has been cleaned out by flushing sediment downstream into the bay. Due to ODF&W concerns regarding flushing this material into the bay, it is now removed by clamshell, backhoe or dragline and placed upland.

4. Depoe Bay is mainly used by commercial, recreational and charter fishing boats. A U. S. Coast Guard station is located in the bay as well as a boat repair facility and two fish buyers. Salmon, crab, and to a lesser extent halibut, groundfish and sable are the main commercial fishery (2).

Previous Studies

5. Sediment evaluations of Depoe Bay were conducted in 1980 and 1989 (1,3). The results of these studies showed that the sediment is clayey silt except near the opening of the entrance channel into the bay where the sediment is more sandy (see figure 1). Contaminants in the sediment are generally below concern levels. Heavy metals, pesticides, PCBs and organotins were below established levels of concern. Polynuclear aromatic hydrocarbons (PAHs) were somewhat elevated but not to levels that are known to be toxic in sediment

bioassays using amphipods (8). Elutriate tests of sediment, conducted in 1980, revealed that elutriate water contained non-detects or very low levels of contaminants (3). Contaminants such as ammonia, manganese and phenols were released at higher levels but these were not considered problematic because of anticipated dilution during disposal operations. The sediment from Depoe Bay was considered acceptable for unconfined in-water or upland disposal.

Current Study

6. The Portland District attempts to evaluate project sediments every five years, or as needed. Since the last evaluation was conducted five years ago in March of 1989 and dredging is proposed for this fall, it was considered appropriate to conduct another evaluation.

7. The main purpose of the current study was to determine if sediment from the Depoe Bay Federal Project is acceptable for unconfined in-water ocean disposal. In-water disposal will be evaluated according to guidelines developed to implement the Marine Protection Research and Sanctuaries Act (MPRSA) and the Clean Water Act (CWA). Another purpose of the current study was to acquire information to obtain state 401 water quality certification.

Methods

8. Eight sediment samples were collected from the bay on 8 February 1994 (see Figure 1 for locations). Two of these, DB-GC-1 and 2, were collected by gravity corer in the more silted-in area of the bay. The two cores were considered representative of the proposed dredging prism. Core lengths were 3'3" and 2'4" respectively. The cores were split in half lengthwise and each half was subsampled along its entire length from material not in contact with the plastic core liner. The integrated subsamples of each core were subjected to physical and chemical analyses. The other six samples, DB-P-3, 4, 5, 6, 7 and 8, were taken by ponar grab sampler. All of the six ponar samples were subjected to physical analysis. Three of the ponar samples, DB-P-3, 4 and 7, were composited into one sample for chemical analysis. Ponar sample, DB-P-6, was also subjected to chemical analysis. Thus, four samples were analyzed for contaminants - two gravity core and two ponar (one a composited ponar sample).

9. Physical subsamples were placed in plastic baggies and were analyzed for volatile solids (organic content), grain size distribution, resuspended density, void ratio, specific gravity and particle roundness by the USACE, North Pacific Division Materials Testing Laboratory, Troutdale, Oregon.

10. Chemical subsamples were placed in properly cleaned glass jars with teflon lined lids. The jars were sealed inside plastic baggies and were cold stored until analysis. The samples were analyzed for metals, acid volatile sulfides (AVS), PAHs, pesticides, PCBs, phenols, tributyltin (TBT) and total organic carbon (TOC). Analyses were performed by Columbia Analytical Associates (CAS), Kelso, Washington. All analyses were performed consistent with the quality assurance program of the testing laboratory - CAS.

11. All sample collection, handling, storage and analyses were performed according to guidelines developed and approved by EPA and USACE (5).

Results

Physical

12. The samples were predominantly sandy, clayey silts with the exception of sample DB-P-5, taken near the opening of the entrance channel to the bay, which was silty sand (Table 1). Entrance channel samples tend to be rocky and sandy whereas boat basin samples were silty. This pattern follows that of previous samples taken in the bay (1,2) Excluding the sandy sample, the others averaged about 40 % sand, 50 % silt and 10 % clay. The samples were high in organic content averaging about 13 % volatile solids (Table 1) and 6.5% TOC (Table 3). The median grain size averaged 0.068 millimeters, that of coarse silt. These physical attributes of Depoe Bay sediment are typical of small boat basins in backwater or protected areas fed by streams and rivers along the Oregon coast. The fine-grained, high organic nature of the sediment indicates a potential to trap contaminants, depending on exposure. The chemical results that follow show that contamination of the sediment in the boat basin area is minimal.

Chemical

Metals/AVS

13. Heavy metals in the samples were below established concern levels except for cadmium and zinc (Table 2). Cadmium exceeded the EPA, Region 10 and USACE, Portland District screening levels in the two ponar surface samples but not the two gravity core samples. This suggests that higher concentrations are found in the surface layer of sediment. Zinc exceeded the EPA screening level in all four samples and the Portland District concern level in two samples. The zinc levels were also higher in the surface ponar samples versus the gravity core samples.

14. The AVS concentration in Depoe Bay sediment averaged 3,550 ppm (Table 2). The surface ponar samples contained less AVS than did the gravity core samples. Converting to molar concentration yields an average molar concentration of 104.1 $\mu\text{M}/\text{gram}$ sediment for all four samples. The average molar concentration of the ponar surface samples was 136.4 $\mu\text{M}/\text{gram}$ and for the core samples 71.8 $\mu\text{M}/\text{gram}$.

Organics

Pesticides/PCBs

15. No pesticides were detected in the samples (Table 3). Detection limits were well below established concern levels. Of seven PCB arochlors only arochlors 1254 was detected at concentrations that were four to ten times below established concern levels for total PCBs (Table 3).

TBT

16. TBT was detected in all the samples at concentrations below the established concern level (Table 3). The levels detected are similar to levels found in 1989 (1). In contrast to the

results for cadmium and zinc, the surface samples contained less TBT than gravity core samples.

TOC

17. The organic carbon content (TOC) averaged 6.45 percent in the sediment (table 3). This is fairly typical of organic-rich, fine-grained sediment.

PAHs

18. Fifteen of seventeen PAHs were detected in the sediment (Tables 4 and 5). The number of different PAHs detected ranged from nine in DB-GC-1 to fifteen in the composite sample, DB-P-3, 4, 7. Detected PAHs ranged from 23 ppb for acenaphthalene to 970 ppb for fluoranthene.

19. Four HMW PAHs exceeded EPA, Region 10 screening levels in some of the samples (Table 5). These were fluoranthene, pyrene, benz(a)anthracene and indeno(1,2,3-cd)pyrene. Composite sample DB-P-3,4,7 exceeded concern levels for all four of these PAHs. None of the LMW PAHs detected in any sample exceeded established concern levels (Table 4).

20. The total PAHs in the samples ranged from 1,022 to 4,373 ppb. A breakdown of major categories of PAHs shows that an average of about nine times more high molecular weight PAHs were detected than low molecular weight PAHs (2,181 ppb vs 237 ppb). Three of the four samples exceeded the concern level for total HMW PAHs (Table 5). None of the samples exceeded the established concern levels for total LMW PAHs (Table 4).

21. As in the case of cadmium and zinc, the surface samples contained more PAHs than the gravity core samples.

Discussion

Metals

22. It is not unusual to find somewhat elevated cadmium and zinc in fine-grained sediment. These elements are often associated with each other in rock. The pattern found at Depoe Bay appears in many small boat basins along the coast and even in backwater areas of the Columbia River not associated with marina locations (4-7,16). An explanation might be that fine-grained material has more cadmium and zinc available on the exposed surface area in the crystalline lattice for chemical attack by extraction acids than does larger-grained material.

23. Another possible explanation is that fine-grained material differentially adsorbs these elements from the water column, especially from urban run-off water, which is known to contain heavy metals. Lead, cadmium, copper and zinc are most often found at elevated levels in urban runoff (10). Each of these elements appears elevated in the surface ponar samples compared to the gravity core samples indicating a possible increased contribution of these from recent urban runoff from the nearby highway and adjacent town of Depoe Bay (Table 2). This possible explanation should be tempered by the fact that it is based on results from only four samples.

24. Mr. Terry Owenings, city manager at Depoe Bay, provided some information regarding storm drain outlets to the bay. Three storm drains deliver stormwater to the bay from the north and east sides. Additionally, the street system above North Creek probably delivers runoff to the creek before it enters the bay. Stormwater from the surrounding area could contribute heavy metals to the bay and account for the somewhat elevated metals concentrations.

25. Over time the zinc concentration has apparently increased in the sediment. In 1980 the concentration was measured at 111 ppm (one sample), in 1989 at 145 ppm (two samples) and in 1994 at 227 ppm (4 samples) (1,3). The digestion and analytical procedures used were similar on all three occasions so the results of the three studies probably reveal a real trend.

26. A probable explanation for the high zinc levels in the sediment may be the pilings used to anchor the four floating docks near the seawall. According to Owenings, the pilings are protected by zinc blocks that are below the water line and near the sediment surface. Possibly these blocks are the source of elevated zinc in the sediment. In the current study most of the sediment sampling stations were near the piling-ends of the floating docks. In 1989, samples were also taken above the check dam located upstream from the bay in an area removed from influences on the bay. A comparison of zinc concentration in these check dam samples to bay samples shows them to have roughly half as much zinc - 70 ppm versus 145 ppm.

27. Over time, the zinc concentration in sediment should decrease as the pilings with zinc blocks are gradually being removed and replaced.

28. Zinc is one of the least toxic of the heavy metals (11). Its toxicity is inversely related to dissolved oxygen level in water (3). The oxygen level in disposal water is expected to be saturated. The zinc concentration in sediment can be very high compared to other metals before toxicity concerns are raised (see SLs in Table 2). The Portland District concern level for sediment is 250 ppm and the State of Washington is 410 ppm for marine sediment. The Depoe Bay sediment samples (227 ppm) are below these concern levels and therefore are not likely to be of concern regarding toxicity to aquatic organisms at the disposal site. The water column at the disposal site is expected to be free of zinc contamination. In support of this conclusion are elutriate test results from 1980 that show zinc was not released to receiving water at levels above the current water quality criterium. The disposal site mixing zone would further reduce zinc concentrations in receiving water to levels far below toxic concerns.

AVS

29. Acid volatile sulfide (AVS) in sediment is important because it may serve as a reactive pool that binds metals to sulfur rendering the metals insoluble and therefore less toxic to aquatic organisms (12,13). AVS is measured by extracting the sediment with cold HCL acid. In the process some metals are also extracted. These are called simultaneously extracted metals (SEM) (12,13). While SEM was not measured in the sediment, the extraction procedure used for metals in bulk sediment, EPA Method 3050, is more harsh and probably extracts more metals from the sediment than cold HCL extraction does. So the metals concentrations shown in Table 2 are probably greater than the SEM that would have been extracted in the AVS procedure.

30. By using the Table 2 metals concentrations in lieu of the SEM concentrations some conclusions can be drawn. The combined average molar concentration of all the heavy metals was 5.7 $\mu\text{M}/\text{gram}$ sediment. This means the SEM concentration is probably less than 5.7 $\mu\text{M}/\text{gram}$ sediment. When the molar ratio of SEM to AVS exceeds 1.5 to 2.5 in sediment, the mortality of sensitive species increases (13). When the ratio is lower, organisms are protected from the toxic effects of metals. The AVS concentration is about 21 times greater than the metals concentration in bulk sediment. It's likely the SEM to AVS ratio in Depoe Bay sediment is much less than 1.5. This means that metals such as zinc and cadmium, which are elevated in the sediment, are not in a form in situ that is toxic to aquatic organisms.

31. The protective effect of AVS is promoted in reduced, anoxic sediment where the conditions are favorable for the reactions of sulfur with metals to proceed. Dredging or disposal operations that lead to oxic conditions could release metals from the AVS reactive pool. Consequently, increased toxicity to aquatic organisms could result if metals were abnormally elevated in sediment. Because Depoe Bay sediment is low in heavy metals contaminants, hydraulic dredging, which increases dissolved oxygen levels in the slurry, is not likely to result in significant releases of metals at toxic concentrations.

32. Elutriate tests, conducted in 1980, of Depoe Bay sediment support this view (3). Elutriate tests mimic sediment-water slurry conditions during hydraulic dredging and are predictors of worst case release of contaminants to the water column (9). None of the heavy metals that were measured in the current study exceeded water quality criteria in the 1980 study of elutriates. Of twenty-seven parameters measured only four exceeded applicable water quality standards at the time. These four, ammonia, manganese, iron and phenols are known to be readily released in elutriates. They were not found at toxic levels in the bulk sediment. They were not at levels in elutriate water that are considered toxic or bioaccumulative.

Pesticides/PCBs/TBT

33. Pesticides, PCBs and TBT in bulk sediment were well below established concern levels (Table 3). The 1980 elutriate tests also showed that these chemicals were at concentrations in elutriate water that are below current water quality criteria and therefore the LPCs. The mixing zone at the disposal site will even further reduce the concentrations of these chemicals. Thus, adverse environmental impacts due to acute or chronic toxic effects from these chemicals are not expected to result from in-water disposal.

PAHs

34. As can be seen in Table 5 some individual and total HMW PAH concentrations exceeded established EPA, Region 10 screening levels. The exceedances were minimal compared to typically polluted sites where individual PAHs can range into the thousands of ppb. The EPA, Region 10 screening levels are set at roughly 100 times lower than concentrations known to have acute toxic effects.

35. To put Depoe Bay PAHs into perspective Table 6 shows PAH levels at various locations worldwide. The table shows that Depoe Bay sediments are at the low end of the range.

36. Another way to evaluate the PAH levels is to carbon normalize the concentrations. This was suggested by EPA, Region 10 as a means of evaluating the significance of marginal exceedances of screening levels for PAHs. The calculation is performed by dividing the sediment dry weight concentration in ppm by the dry weight decimal fraction of the percent total organic carbon (TOC). This is a procedure used by the State of Washington in comparing sediment PAHs to their carbon normalized marine sediment quality standards. Table 6 shows the results of carbon normalization for all the PAHs in the Depoe Bay samples. From the Table it can be seen that sediment from Depoe Bay is far below the carbon normalized standards used by Washington State to protect aquatic life.

MPRSA Evaluation

37. The specified disposal site at Depoe Bay is in an area adjacent to the shoreline. Sediment is hydraulically dredged and the slurry is pumped out onto the rocky shoreline where it runs down into the water. Disposal at the site would ordinarily be evaluated using guidelines developed to implement the Clean Water Act (CWA). However, the CWA guidelines are currently under revision. Therefore the Corps and EPA have agreed, via Memorandum of Understanding (MOU), that, in the interim, in-water ocean disposal will be evaluated using guidelines developed to implement the Marine Protection Research and Sanctuaries Act (MPRSA). MPRSA guidance is published in the "Green Book", officially titled Evaluation of Dredged Material Proposed for Ocean Disposal (Testing Manual).

38. The "Green Book" uses a tiered testing approach to evaluate sediment in terms toxicity impacts of disposal (Figure 2). Tier I allows for determining the acceptability of disposal based on sufficiency of existing information. In the case of Depoe Bay, existing information, combined with that collected in the current study, is sufficient to determine whether the sediment is acceptable for disposal.

39. The "Green Book" uses the concept of limiting permissible concentrations (LPCs) for contaminants of concern in assessing toxicity impacts of disposal. In the aquatic environment contaminants in sediment may exert toxic effects in the liquid, suspended and solid phase. The LPC for the liquid phase is defined as the established water quality criterium (WQC) for a given contaminant of concern. Thus the LPC is the WQC if the WQC is established. If the WQC is not established then the LPC is 0.01 of the acutely toxic concentration as determined by bioassay. For the suspended and solid phases, the LPC is the concentration that will not cause unreasonable toxicity or bioaccumulation.

Liquid Phase LPCs

40. Since cadmium, zinc and PAHs were near screening levels in the sediment their LPCs in the liquid phase were evaluated. Information from elutriate tests is used to determine if sediment meets liquid phase LPCs. Elutriate tests mimic the ratio of sediment to water in the hydraulic dredged material slurry that passes through the pipes to the disposal site. Thus elutriate tests determine the predicted concentrations of contaminants of concern in dredged material water as it leaves the pipe and enters the aquatic environment at the disposal site.

41. Past elutriate studies of sediment from Depoe Bay have shown that LPCs were not exceeded in receiving water for contaminants of concern such as metals and pesticides (3). For the metal zinc, however, there was no WQC established in 1980. In 1994 the established WQC for zinc is 96 $\mu\text{g/L}$ (15). Applying the current WQC to the 1980 elutriate samples shows that zinc did not exceed the present day WQC. The highest amount of zinc released to elutriate water in the 1980 elutriate samples was 0.090 mg/L from a sediment sample containing 40.9 mg/L (wet weight) of zinc. Converting to $\mu\text{g/L}$ yields a value of 90 $\mu\text{g/L}$. That amount of zinc, is below the current WQC (96 $\mu\text{g/L}$) for marine water.

42. It is possible that, because the current level of zinc in the sediment is higher than it was in 1980, the WQC will be temporarily exceeded at the disposal site. Using 1980 elutriate data, the ratio of zinc in elutriate water to zinc in the sediment was 0.0022 (0.090 mg/L ÷ 40.9 mg/L = 0.0022). The current sediment samples average 99.4 mg/L zinc (see Appendix, item 1). Assuming the same ratio of zinc is released to elutriate water from the current sediment samples that contain 99.4 mg/L zinc, then about 0.218 mg/kg zinc (0.0022 x 99.4 mg/L) is predicted to be released. This assumption is reasonable because conditions at Depoe Bay have not appreciably changed since 1980. Converting to $\mu\text{g/L}$ yields 218 $\mu\text{g/L}$. The predicted slurry water concentration of 218 $\mu\text{g/L}$ is about 2.3 times the acute WQC of 96 $\mu\text{g/L}$. That amount of zinc could potentially be in the dredge slurry water as it leaves the pipe and enters ocean water at the disposal site where dilution will occur. To be conservative ten times this amount 2,180 $\mu\text{g/L}$ (or 2.18 mg/L) will be used in the mixing zone calculation described in the next section.

Initial Mixing vs Mixing Zone

43. Typically, in an MPRSA evaluation, the concept of initial mixing would be used to evaluate the potential concentration of a contaminant in the environs of the disposal site. Initial mixing is defined as "that dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within four hours of dumping. The limiting permissible concentration shall not be exceeded beyond the boundaries of the disposal site during initial mixing and shall not be exceeded at any point in the marine environment after initial mixing" (9). In an MPRSA evaluation initial mixing is used in conjunction with a "designated" ocean disposal site. Designated sites have specific dimensions and locations and the concept of initial mixing is tailored to the site. However, the site at Depoe Bay is a "specified" site because it is in waters covered by the CWA. Specified CWA sites are evaluated using the concept of the "mixing zone". This zone is defined by the dimensions of the volume of water that are required to dilute a contaminant concentration to below the WQC standard. The Green Book guidelines for evaluating MPRSA initial mixing do not cover instances where disposal is a continuous hydraulic discharge as is the case for Depoe Bay. Since the CWA mixing zone concept is more appropriate for the type of disposal site and disposal method it will be used to evaluate projected water column concentrations for zinc.

44. The first step in sizing the mixing zone is to estimate the volume of disposal site water needed per unit of time to dilute a contaminant of concern as it leaves the dredge pipeline. An equation for calculating the rate of flow of disposal site water needed to dilute the slurry water to an acceptable level is presented in the Appendix, item 2. The equation was taken from the inland waterways manual of 1976 (14). A conservative assumption was made that ten times the predicted amount of zinc (218 $\mu\text{g/L}$) actually is released to the slurry water (2180

µg/L). The dilution of this amount of zinc should be rapid and occur over a short distance. The calculation shows that about 1,008 cubic feet per second (cfs) of site water are needed during dredging operations to dilute 2180 µg/L zinc to an acceptable level (96 µg/L).

45. The next step is to determine the dimensions of the mixing zone necessary for dilution to occur. Unfortunately, no models are available that predict mixing zone dimensions for a situation like Depoe Bay where a hydraulically dredged slurry pours down a rocky slope into the ocean. Most models cover riverine, estuarine or offshore conditions. After consultation with experts at the Waterways Experiment Station it was decided that the mixing zone calculation should be based on the dilution volume method as described in the draft inland testing manual, pages B34 to B38. It was felt that this method would yield a conservative estimate of mixing zone dimensions and that it would more accurately reflect the vigorous mixing conditions at the site. Both the selected model and the assumed zinc concentration of 2180 µg/L (2.180 mg/L) will make the calculated mixing zone conservatively large. The dilution volume method yields a mixing zone that is 50 feet wide by 180 feet long by 20 feet deep (Appendix, item 3).

46. The dimensions of the calculated theoretical mixing zone are conservative and overestimate its size because of the turbulent conditions at the Depoe Bay site. Wave action is brisk along the rocky shoreline. The slope to the ocean bottom is steep and the bottom is about 20 feet below the surface. These factors lead to vertical and lateral mixing that should be much greater than in a riverine or open water disposal situation. Most of the disposal material will settle to the bottom but, due to its fine-grained nature, some will be resuspended causing an increase in turbidity.

47. In this region of the coast there is a longshore ocean current of about 1 foot/second to the north (winter) or south (summer) along the coastline(18). The local current at the disposal site is affected by the tide, with ebb tide generally causing southerly flow and flood tide causing northerly flow (18). Local currents may also be affected by the shape of the coastline near Depoe Bay. About 1,650 feet North of the bay and about the same distance south, the coastline dips inland to form a roughly rectangular indentation (Figure 2). The seaward side of the rectangle is bounded by two reefs, each about 1,000 feet long, that are submarine extensions of the coastline where it dips inward north and south of Depoe Bay. The combination of reefs and indented coastline cause wave refractions that probably affect local currents (17). These current interactions add to the dynamic nature of the disposal site and thus the dispersion of material.

48. In regards to the two other contaminants of concern, cadmium and zinc, the mixing zone for zinc is more than sufficient for diluting them to acceptable levels, assuming all the cadmium and PAHs in bulk sediment dissolved into the slurry water. This is an extremely conservative assumption. Calculations show the required dilution rate from disposal site water is less than that for the zinc (Appendix, item 4). It is not likely conditions at the dredge site are such that all the cadmium in the sediment would dissolve into slurry water. Even if it did, the cadmium would not need to be diluted by disposal site water because its concentration (0.042 mg/L) in the slurry water would be below the WQC (0.043 mg/L). For PAHs the overwhelming evidence is that they remain in the solid phase because of their hydrophobic nature (9). A very small amount will be released to the water column. Even if all the PAHs were released to the slurry water, the zinc mixing zone is more than adequate to dilute them to an acceptable level because

the required dilution for zinc is greater than that for PAHs.

Suspended/Solid Phase LPCs

49. To assess suspended/solid phase LPCs the concentrations of Cadmium and zinc were compared to Portland District screening levels and to Washington State Standards for sediment. The screening levels are very conservative and are set to assure no unreasonable toxicity or bioaccumulation. According to the comparisons cadmium and zinc concentrations in the sediment are such that no unreasonable acute or chronic toxicity or other sublethal adverse effects are expected in either the suspended or solid phases.

50. In consultation with EPA, Region 10, it was decided that the carbon normalized data for PAHs would be used to evaluate the likelihood that LPCs would be met in suspended and solid phases. The carbon normalized data were compared to Washington State Standards for sediment (Table 5). The Washington State Standards were set to result in "no adverse effects, including no acute or chronic adverse effects on biological resources and no significant health risk to humans". The comparisons show that solid phase concentrations are below the standards (Table 5). Since PAHs partition into the solid phase it is expected that they will remain in the solid fraction of the suspended phase and that no unreasonable acute or chronic toxicity or bioaccumulation will occur as the result of exposure of marine organisms to the suspended phase as well.

State Water Quality Certification

51. The active nature of the ocean at the disposal site would rapidly accomplish the required dilution of zinc, cadmium and PAHs and acute toxicity would not reasonably be expected to occur. Information from bulk sediment studies, elutriate tests and mixing zone calculations support this conclusion.

Other Effects

52. A temporary turbidity plume may exist during disposal operations at the site. The plume will be dispersed as the result of wave action and ocean currents. The shore drops off rapidly at the site into the subtidal region. Much of the dredged material will settle quickly to the bottom at the disposal site. Wave action will also quickly restore dissolved oxygen levels in the dredged material slurry after it leaves the pipeline.

53. Wave "throwback" may spread silty water back up onto the rocky shoreline thereby affecting tidal organisms residing on the rocks. Informal observations over the years and the results of a Corps study indicate that tidal organisms in the affected zone recover within a year or two (17). Wave action will remove fine-grained material from the rocky area in the interval between dredging episodes.

Conclusions

54. The combined results from three bulk sediment studies and an elutriate study are sufficient to show that Depoe Bay sediment is acceptable for in-water disposal and that no

unacceptable adverse impacts to the aquatic environment will result from such disposal. This conclusion is based on a tiered testing evaluation of the sediment using guidelines developed to implement the MPRSA.

55. In-water disposal is not expected to violate State water quality standards.

REFERENCES

1. Siipola, M. U. S. Army Corps of Engineers. 1989. Results of 1989 Depoe Bay Sediment Quality Evaluation.
2. Navigation Branch, Operations Division, U. S. Army Corps of Engineers, Portland District. September 1991. Federal Navigation Projects: Columbia River Maintenance Disposal Plan. (Prepared by Mandaville Associates, 600 S. W. Tenth #418, Portland, Oregon 92205)
3. Moore, P. U. S. Army Corps of Engineers. 1980. Depoe Bay sediment quality study, 7 April 1980.
4. Britton J. U. S. Army Corps of Engineers, Portland District. 20 July 1992. Evaluation of Sediment at U. S. Coast Guard Station Ilwaco, Washington.
5. Britton J. L., Siipola M. and Malek J. December 1992. Characteristics of Chinook Marina sediment in Baker Bay, Washington. Prepared by the U. S. Army Corps of Engineers, Portland District for EPA, Region 10, Seattle, Washington.
6. Britton J. L., Siipola M. and Malek J. December 1992. Characteristics of Ilwaco Boat Basin sediment in Baker Bay, Washington. Prepared by the U. S. Army Corps of Engineers, Portland District for EPA, Region 10, Seattle, Washington.
7. Britton J. U. S. Army Corps of Engineers, Portland District. 21 August 1991. Skipanon River Sediment Evaluation.
8. Crecelius, E. Battelle Marine Sciences. 1989. Letter, dated 15 March 1989, describing significance of PAH results reported by Battelle to Portland District.
9. U. S. Environmental Protection Agency and U. S. Army Corps of Engineers. May 1993. Evaluation of Dredged Material proposed for Discharge in Inland and Near Coastal Waters - Testing Manual (Draft) (Inland Testing Manual).
10. Thomas Schueler. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for Washington Metropolitan Water Resources Board.
11. Connell, D. W. and Miller, G. J. 1984. Chemistry and ecotoxicology of pollution. A Wiley-Interscience Publication, John Wiley & Sons.
12. DiToro, D.M., Mahony, J.D., Scott, K.J., Hicks, M.R., Mayr, S.M., and Redmond, M.S. Feb. 1990. Toxicity of Cadmium in sediments: the Role of Acid Volatile Sulfide. Environmental Toxicology and Chemistry, in press.
13. DiToro et al. Acid Volatile Sulfide Predicts the Acute Toxicity of Cadmium and Nickel in Sediments. Environ. Sci. Technol. 1992, 26, 96-101.

14. Environmental Effects Laboratory, U. S. Army Waterways Experiment Station, Vicksburg, MS. May 1976. Ecological evaluation of proposed discharge of dredged or fill material into navigable waters. (Interim guidance for implementation of section 404(b)(1) of public law 92-500 (Federal Water Pollution Control Act Amendments of 1972).
15. U. S. Environmental Protection Agency. May 1986. Quality Criteria for Water ("The Gold Book"). Office of Water Regulations and Standards. Washington, DC.
16. Tetra Tech. 1994. Lower Columbia River backwater reconnaissance survey, volume 1: reconnaissance report. Draft Report TC 9497-06 for the Lower Columbia River Bi- State Program.
17. U. S. Army Corps of Engineers, Portland District. October 1978. Intertidal disposal of dredged material at Depoe Bay, Oregon: an analysis of effects.
18. U. S. Army Corps of Engineers, Portland District. April 1985. Yaquina Bay Interim Ocean Dredged Material Disposal Site Evaluation Study.

APPENDIX

1. Convert zinc, cadmium and total PAHs concentrations in sediment from dry weight basis (mg/kg) to volumetric basis (mg/L).

For zinc,

$$= (\text{density of sed. kg/L}) (\text{fract of sed. as solids}) (\text{dry wgt. conc. of zn mg/Kg})$$

$$= (1.203 \text{ kg/L}) (0.364) (227 \text{ mg/Kg}^*)$$

$$= 99.4 \text{ mg/L} \quad \text{* (used ave. dry wgt. Zn conc. from Table 2)}$$

For cadmium,

$$= (1.203 \text{ kg/L}) (0.364) (0.096 \text{ mg/Kg})$$

$$= 0.042 \text{ mg/L}$$

For total PAHs,

$$= (1.203 \text{ kg/L}) (0.364) (2.418 \text{ mg/Kg})$$

$$= 1.059 \text{ mg/L}$$

2. Calculate volume disposal site water needed to dilute zinc to below acute WQC.

First, determine volume of site water/unit of time needed to dilute the zinc in slurry.

$$V_a = V_p (C_e - C_s) / (C_s - C_a)$$

$$= 44 (0.218 \text{ mg/kg} - 0.096 \text{ mg/kg}) / (0.096 \text{ mg/kg} - 0.005 \text{ mg/kg})$$

$$= 1,007.6 \text{ cfs}$$

V_p = rate of effluent discharge, cfs

C_e = conc. in elutriate, mg/L

C_s = WQC, water quality criterium, mg/L

C_a = conc. in disposal site water, mg/L

3. Calculate mixing zone dimensions using the dilution volume method for continuous discharge as presented in the draft inland testing manual, ppB34-B38, assuming ten times the predicted concentration of zinc dissolves into the water column (2.18 mg/kg).

Calculate the width of the front edge of the mixing zone.

$$L = V_a / d V_w$$

$$= (1007.6) / (20 \text{ ft}) (1.0)$$

$$= 50.4 \text{ ft}$$

L= width of mixing zone
 V_w= ave. water velocity at site
 d= ave. depth at site, ft

Calculate the time required for the front edge of the mixing zone to spread laterally to width L.

$$t = 1 / \lambda (0.094 L^{2/3} - 0.149 r^{2/3})$$

$$= 1 / 0.005 (1.34 - 0.43)$$

$$= 180 \text{ seconds}$$

λ= turbulent dissipation parameter (0.005)
 r= one-half initial width of plume at point of discharge, 5 ft

Calculate length of mixing zone.

$$X = V_w t$$

$$= (1.0) (180)$$

$$= 180 \text{ ft}$$

X= length of mixing zone, ft

Calculate area of mixing zone.

$$A = [(L + 2r) / 2] X$$

$$= (31.5)(180)$$

$$= 5,436 \text{ ft}^2$$

A= area of mixing zone, ft²

4. Determine the dilution per unit time required for cadmium and total PAHs assuming all that is in the bulk sediment is released to the dredge slurry water. If less than that for zinc then the mixing zone for zinc is more than adequate for these contaminants.

$$V_a = V_p (C_e - C_s) / (C_s - C_a)$$

For cadmium, calculation is not necessary since assumed concentration (0.042 mg/L, Appendix, item 1) is below the WQC (0.043 mg/L). No dilution necessary.

For total PAHs,

$$= 44 (1.059 - 0.300) / (0.300 - 0.005)$$

= 113 cfs

For zinc,

= 1,008 cfs (from Appendix, item 2)

Table 1. Physical characteristics of Depoe Bay sediment.

sample	median gr. size mm	sand	silt	clay	volatile solids
		%			
DB-GC-1	0.066	51.9	37.7	10.4	12.3
DB-GC-2	0.025	29.2	57.1	13.7	16.3
DB-P-3	0.055	30.4	57.1	12.5	19.4
DB-P-4	0.046	33.2	55.4	11.4	10.5
DB-P-5	0.180	97.1	2.9	-	2.5
DB-P-6*	0.054	40.0	60.0	-	15.1
DB-P-7	0.064	50.6	41.8	7.6	12.9
DB-P-8	0.057	44.1	49.8	6.1	12.8
mean	0.068	47.1	45.2	10.3	12.7

* Median grain size extrapolated from data. Clay content was not determined in this sample.

Table 2. levels of metals and AVS in Depoe Bay sediment.

sample	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn	AVS
	ppm									
DB-GC-1	11.4	0.73	34.7	33.8	13.2	0.08	23.5	0.15	186	4000
DB-GC-2	13.1	0.69	46.5	37.5	17.0	0.10	29.4	0.24	178	5300
DB-P-3,4,7	13.9	1.65	43.3	45.3	15.3	0.09	32.7	0.22	284	2800
DB-P-6	15.0	1.12	41.7	44.8	16.8	0.09	30.5	0.18	259	2100
mean	13.4	1.05	41.6	40.4	15.6	0.09	29.0	0.20	227	3550
SL*	57.0	0.96	180.0	81.0	66.0	0.21	140.0	1.20	160	-

* EPA, Region 10 screening levels for marine waters.

Table 3. Pesticides, PCBs, TBT and organic carbon in Depoe Bay sediment.

sample	pesticides	PCBs [^]	TBT	TOC
		ppb		%
DB-GC-1	<2-<6	10	18	5.50
DB-GC-2	<2-<6	<10	12	6.58
DB-P-3,4,7	<2-<6	20	9	6.67
DB-P-6	<2-<6	30	8	7.14
SL*	10	130	30	-

* EPA, Region 10 screening levels for marine waters.

[^] Of seven arochlors, only arochlor 1254 was detected at levels shown.

Table 4. Concentrations of detected low molecular weight PAHs in Depoe Bay sediment.

sample	low molecular weight PAHs (LMW)						total LMW PAHs
	acenaphthalene	dibenzofuran	acenaphthene	fluorene	phenanthrene	anthracene	
	ppb						
DB-GC-1	<20	<20	<20	<20	65	52	117
DB-GC-2	<20	<20	<20	<20	73	49	122
DB-P-3,4,7	23	33	32	55	230	110	483
DB-P-6	<20	<20	<20	25	130	69	224
SL*	64	54	63	64	320	130	610

* EPA, Region 10 screening levels for marine waters.

Table 5. Concentrations of detected high molecular weight PAHs in Depoe Bay sediment.

sample	high molecular weight PAHs (HMW)									total HMW PAHs
	fluor-anthene	pyrene	benz(a)anthracene	chrysene	benzo(b+k)fluoranthene	benzo(a)pyrene	indeno(1,2,3-cd)pyrene	dibenz(a,h)anthracene	benzo(g,h,i)perylene	
ppb										
DB-GC-1	220	250	83	130	130	46	46	<20	<20	905
DB-GC-2	370	620	170	290	260	79	76	25	28	1918
DB-P-3,4,7	970	890	470	560	550	170	170	53	57	3890
DB-P-6	440	450	210	330	290	110	110	32	39	2011
SL*	630	430	450	670	800	680	69	120	540	1800

* EPA, Region 10 screening levels for marine waters. Bold numbers exceed SL.

Table 6. Carbon normalized PAHs in Depoe Bay sediment.*

chemical parameter	mg (dry wgt)	kg TOC	mg/kg carbon [^] carbon normalized	Washington sed. qual. std.
total lpah	0.483	0.0667	2	370
acenaphthalene	0.032	0.0667	1	66
fluorene	0.055	0.0667	1	23
phenanthrene	0.230	0.0667	3	100
anthracene	0.110	0.0667	2	220
total hpah	3.890	0.0667	58	960
fluoranthene	0.970	0.0067	15	160
pyrene	0.890	0.0667	13	1000
benz(a)anthracene	0.470	0.0667	7	110
chrysene	0.560	0.0667	8	110
benzofluoranthenes	0.550	0.0667	8	230
benzo(a)pyrene	0.170	0.0667	3	99
indeno(1,2,3 cd)pyrene	0.170	0.0667	3	34
dibenzo(a,h)anthracene	0.053	0.0667	1	12
bennzo(g,h,i)perylene	0.057	0.0667	1	31

* Based on sample DB-P-3,4,7, which contained the highest concentration of contaminant. Contaminants were normalized to carbon following the procedure published in Ch. 173-204 WAC-p7, State of Washington code.

[^] None of the carbon normalized contaminants exceeded the Washington State Marine Sediment Quality Standards.

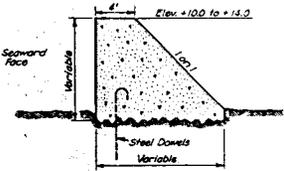
Table 7. Maximum concentrations of total PAHs at various sites around the world.

site	maximum total PAHs~ (ppb)
Southampton Estuary UK	1,791,000
Charles River, MA	120,000
Norway	99,452
New Bedford, MA	63,000
Severn Estuary, UK	25,700
Casco Bay, ME	14,425
Cayuga Lake, NY	13,900
Great Barrier Reef, AUS*	13,400
Adirondack Lakes	12,807
Monaco	12,100
Penobscot Bay, ME	8,794
Boston Harbor, MA	8,500
Tamar Estuary, UK	4,900
Depoe Bay	4,373
Lake Erie, NY	3,750
Amazon River System	544
Gulf of Finland	437
Alaska	113
Walvis Bay, Africa	68
Great Barrier Reef, AUS^	1
median	10,447
mean	109,863
mean, without Southampton Estuary	21,382

~ Data extracted from Table in Eisler, 1987: Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: A synoptic review. Biological Report 85(1.11), U. S. Department of Interior.

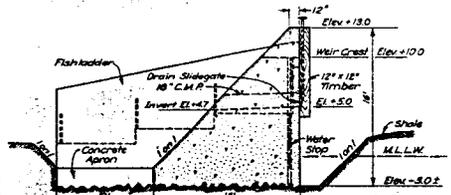
* Great Barrier Reef, Australia at sites frequently visited by power boats.

^ Great Barrier Reef, Australia at pristine sites.

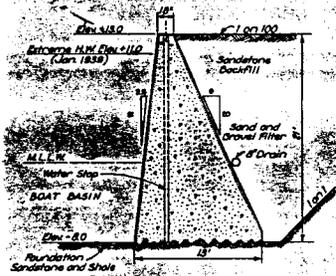


SECTION A-A, BREAKWATER

Note: Base Point of mileage is about 450 feet seaward from highway bridge.

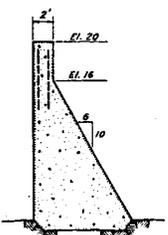


SECTION B-B, CHECK DAM

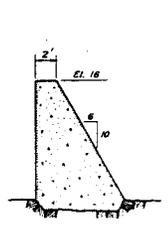


SECTION C-C, RETAINING WALL

TYPICAL SECTIONS
SCALE IN FEET

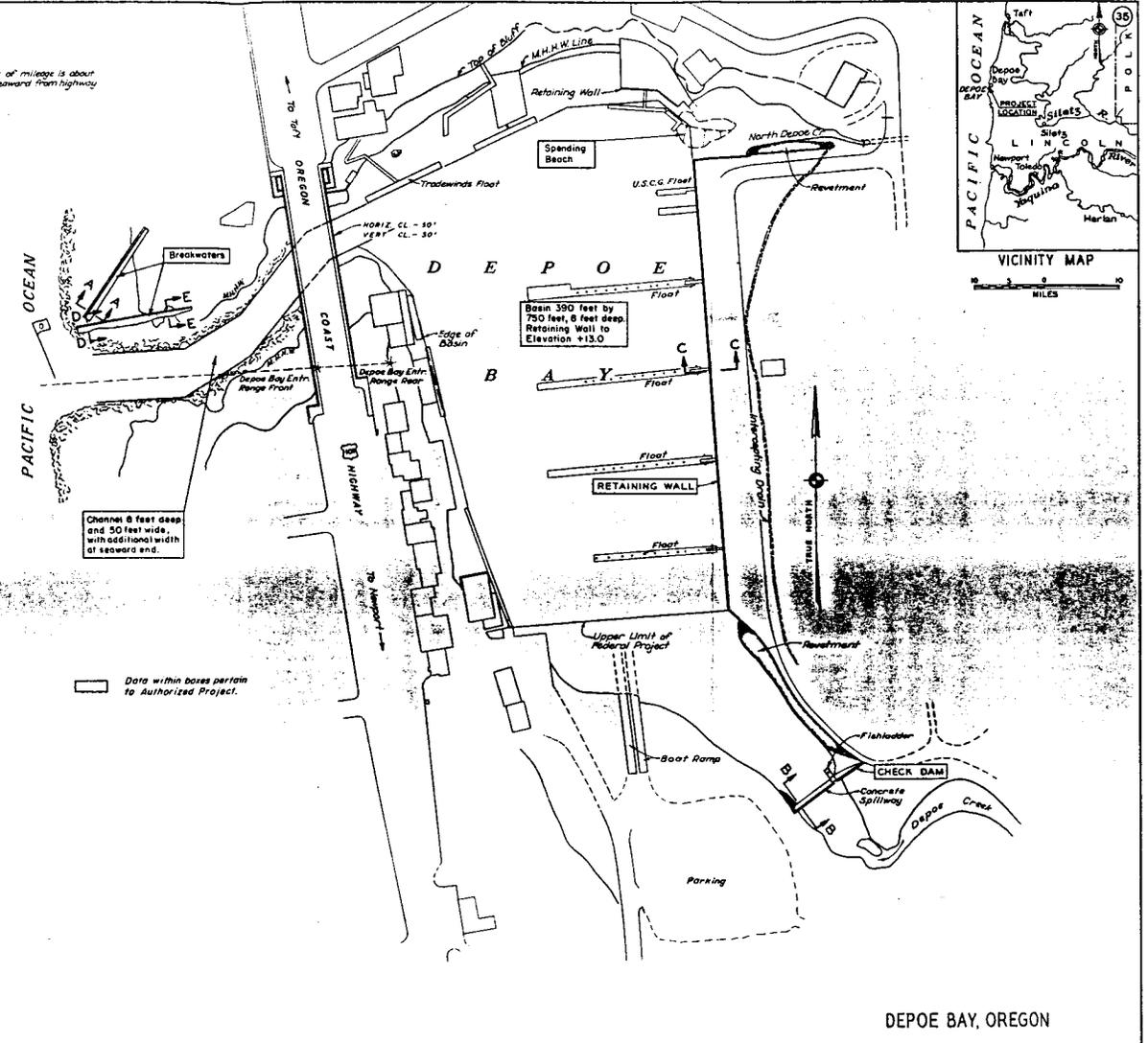


SECTION D-D



SECTION E-E

BREAKWATER
SCALE IN FEET



□ Data within boxes pertain to Authorized Project.

PLAN
SCALE IN FEET
0 50 100 200

DEPOE BAY, OREGON
SCALES AS SHOWN
U. S. ARMY ENGINEER DISTRICT, PORTLAND