Pre-Peer Review Preliminary DRAFT

ENVIRONMENTAL RESULTS ON DREDGING PROJECTS

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Introduction

Dredging is one of several potential remedial alternatives for Superfund contaminated sediments sites. A site specific evaluation is required to determine which alternative (e.g., natural recovery, capping, or dredging) is most appropriate. Dredging is discussed here in order to present factual information on results from environmental dredging projects.

A related issue to dredging effectiveness is the bioavailability and associated risks of contaminants in buried sediments. If other investigations demonstrate that deeper contaminated sediments are not bioavailable under all realistic conditions (e.g., scouring by flood events), then it may indicate that dredging is not appropriate or may even be counterproductive for those sites. However, it should noted that most of these projects are sites where surficial sediments had relatively high pre-dredging contaminant concentrations and/or where the threat of future contaminant releases were present.

Results from these environmental dredging projects demonstrate dredging has reduced contaminant concentration as well as removal of contaminant mass. Dredging has resulted in achieving lower contaminant concentrations in sediments, surface water and fish. Removed contaminants in river environments has also reduced the potential for migration/release into other water bodies, such as the Great Lakes.

Eleven projects evaluated herein include: Allied Paper/Bryant Mill Pond, Michigan; Deposit N, Fox River, Wisconsin; Ford Monroe, Michigan; GM Massena New York; Lake Jarnsjon, Sweden; Pine River (a.k.a., Velsicol), Michigan; Ruck Pond, Wisconsin; Sediment Management Unit 56/57, Fox River, Wisconsin; Sheboygan River, Wisconsin; Shiawassee River, Michigan; Waukegan (a.k.a., Outboard Marine Corp.), Illinois. Except for Lake Jarnsjon, all these projects were located in the Great Lakes. Lake Jarnsjon was also included because the wealth of data provided by the comprehensive monitoring conducted for this project.

The basis for selection of the contaminated sediments projects evaluated is:
1) Availability of pre- and post-dredging monitoring data.
2) Only *completed* projects were considered. Sites not completed or not having final data available were not included. These projects may be added to this evaluation when data becomes available.
3) Environmental dredging projects, as discussed below.

Background on Dredging Techniques

It is important to distinguish among the several different types of dredging projects, as operating conditions are significantly different. Dredging operations have previously been classified based upon the type of devices used (e.g., mechanical, hydraulic or pneumatic). For environmental evaluation, a better distinction is "dry" versus "wet" dredging. Dry dredging involves removing most water from the area, followed by mechanical excavation using conventional earthmoving equipment. Wet dredging is under water, and typically use a hydraulic suction device, clamshell bucket, or other mechanical devices.

Prior to excavation, dry dredging requires pumping water from the area targeted for sediment removal. Prior to pumping out the water, the dredge area is hydraulically isolated (e.g., with dams or sheet piling) or the water body is rerouted. Excavation of dried sediments (e.g., flood plains) is also often considered dry dredging.

Based upon experience on dry dredging projects, dry dredging is more feasible for smaller, shallow water bodies. Advantages for dry dredging are:
1) sediments targeted for removal are clearly visible and more easily located and identified,
2) debris is easier to remove and unlikely to interfere with contaminant removal,
3) there are less materials processing requirements (i.e., dewatering of sediments),
4) less volume of contaminated water requiring treatment (relative to wet dredging), and
5) water column releases from the dredge area more easily controlled.

The following conditions are generally <u>less</u> favorable for dry dredging:
1) deeper water bodies,
2) water bodies subject to high flows that cannot be easily re-routed,
3) contaminants with high concentrations of volatile compounds (i.e., air emissions may be a concern),
4) a dredge area having substantial ground water recharge.

Wet dredging usually requires sediment dewatering after removal, solids handling, solids disposal, and treatment of contaminated water. Wet dredging (especially hydraulic) usually requires treatment of greater water volumes than dry dredging. A typical wet dredging operation sequence includes:

1) Sediment removal with either a mechanical dredge (e.g., clamshell bucket) or a hydraulic suction dredge.
2) Debris screening (sometimes).
3) Dewatering of the dredge solids.
4) Water treatment.
5) Sediment transportation and disposal.

In order to achieve more complete removal of contaminants, wet dredging operations often require more than one dredging "pass." This is done by a dredge excavating a given area two or more times. If an area has debris or bedrock underlying contaminated sediments, it commonly requires multiple "passes."

Based on experience on dredging projects, advantages of wet dredging include:
1) less potential for volatilization from exposure of sediments during dredging, and
2) ground water recharge of dredge area does not impact operations.

Disadvantages by wet dredging are:
1) removal operations often "blind",
2) water flowing over the dredge area during removal typically has greater waterborne releases,
3) shutdowns due to equipment problems, and weather or short-term water level fluctuations are more frequent,
4) sampling and monitoring are more difficult, and
5) water bottom conditions (e.g., debris and material underlying contaminated sediments) may affect removal efficiency.

Environmental Results

Short-term impacts

Contaminant losses on environmental wet dredging projects are generally small relative to contaminants already loading the system. For example, during Phase I of the Deposit N project, Fox River, Wisconsin, it was estimated that 5 pounds of PCBs were released into the surface water during dredging (14). This compares to about 10 pounds of PCBs that would have been released from natural scour and release from this deposit during 1998 if no dredging had occurred (14).

The Sediment Management Unit 56/57 (a.k.a. SMU 56/57), Fox River, Wisconsin wet dredging project also analyzed losses from resuspension of PCBs during dredging. As stated in the USGS report (42):

> "...PCB load into the water-column mass represented less than 2.5 percent of what was dredged from the deposit and approximately 9 percent of what was annually transported by the Fox River in 1994-95."

Additionally, based on comprehensive monitoring for the Lake Jarnsjon project, Elander, 1998 stated: "The spillage from dredging was estimated to be less than 0.5% (9)." Thus, while there are releases from wet dredging, the quantity is typically a fraction of what would have been released due to natural processes (on an annual basis) had no dredging occurred, and represented a small fraction of the mass permanently removed.

Because environmental dredging has only occurred at a relatively small number of sites, only limited data regarding short-term impacts to fish are available. This data suggests that concentration increases are short-lived and less than longer term decreases. For example, at the Shiawassee River, Michigan fish tissue contaminant concentrations increased about 30% approximately 6 months after dredging (33), but subsequently had concentration reductions of 82% (Table 4) (24). On the other hand, at Waukegan Harbor, Illinois, with relatively high PCB concentrations in sediments (exceeding 10,000 ppm), the year after dredging fish PCB concentrations declined 82% (20, 21, 32).

Dredging may also have negative effects due to habitat disruption, but has been observed to be relatively short-term and temporary. For example, the Allied Paper/Portage Creek/Kalamazoo River Site, Michigan, a wetland area excavated during 1998, was observed to recover rapidly and dramatically during the following season (1999) after excavation activities (26).

<u>Long-Term Results</u>

Of ten projects with cleanup goals, eight achieved the sediment cleanup goals. Seven projects had concentration based cleanup standards and three had mass based standards (Table 2). GM Massena and Shiawassee River did not achieve concentration based cleanup goals, although sediment concentration were reduced 99% and 95%, respectively. At the GM Massena Site, boulders and rock debris, and uneven river bottom related to debris removal made achieving cleanup standards difficult. At the Shiawassee River the project stopped prior to completion because, "cost overruns and the presence of contamination extending farther than initially anticipated..." (24) The Sheboygan River was a demonstration project and therefore did not have sediment cleanup goals. However, post-dredging concentrations were reduced 96% (Table 2) (3), and project objectives to evaluate dredging, capping and ex-situ biodegradation were achieved (3).

Sediment data available from two dry dredging projects show that post-dredging sediment contaminant concentrations in the remaining sediments were reduced at least 98% (Tables 1 and 2). In one dry dredging project where surface water and fish data were available, contaminant concentrations in surface water and fish were reduced 94% and 89%, respectively (Tables 1, 3, and 4) (28).

Wet dredging on 8 projects achieved sediment concentration reductions ranging from 12% to 99%, with an average of 79% (Tables 1 and 2). These projects removed more than 360,000 pounds of PCBs residing in contaminated sediments, with five of seven projects evaluated having average concentration reductions of 95% or more. Based on limited data (one project with surface water and three with fish data), post-dredging reductions in surface water and fish averaged 69% and 64%, respectively (Tables 3 and 4).

It should be noted that although the Deposit N, Fox River, Wisconsin wet dredging project only achieved a concentration reduction of 12% in surficial sediments, 111 pounds (or 78%) of the 142 pounds total PCBs present were removed (13). Concentrations were not reduced as much as other wet dredging projects because, as stated in the Summary Report for Deposit N by Foth & Van Dyke, April 2000 (13):

> "The project specifications for removal were intentionally set prior to implementation of the project to remove the majority of contaminated sediment but leave a residual thin layer of sediment behind. The intent was to capture the bulk of the contamination efficiently and cost effectively without exceptional efforts to try and remove the thin layer of residual sediment laying on top of the fractured bedrock surface. However, in projects where total removal is desired, diver assisted dredging and other more specialized equipment is commercially available to achieve this result."

Overall, these dredging projects had contaminant concentration reductions of 84% in sediments, 72% in surface water, and 68% in fish (Table 1). Additionally, about 810,000 pounds of PCB/DDT contaminants in sediments on ten projects were removed (Tables 1 and 2).

Uncertainties

Evaluations of some of these projects were limited by the degree of monitoring and data availability. Most (9 of 11) projects had sediment data, allowing comparison of pre-post- and dredging contaminant concentrations. For some projects, sampled sediment intervals had inconsistencies between pre- and post-dredging sampling. For example, pre-dredging sediment data for Lake Jarnsjon was the top 40 centimeters, whereas post-dredging data was the top 20 centimeters (6). Surface water and fish had limited data, with 2 projects having pre-dredging and post-dredging surface water data and four projects with fish data. While there is uncertainty on individual projects, weight of evidence on multiple projects supports the general conclusion that concentration reductions resulted from the removal of contaminated sediments.

Conclusions

Cleanup goals were achieved on eight of ten projects. For all projects, concentrations were reduced in sediments, surface water, and fish (although surface water and fish data are less complete). Additionally, these projects removed 370,000 pounds of PCBs and 430,000 pounds of DDT (Table 1). Based upon the projects evaluated here, long-term benefits from reductions in concentrations of contaminants and their permanent removal from the aquatic systems appear to outweigh potential adverse short-term biological impacts.

Table1. Summary of Environmental Results for Completed Environmental Dredging Projects

Dredge Type	Project/Year/Primary Contaminants [1]	Volume Removed (cubic yd)	Contaminants Removed (pounds)	Concentration Percent Reductions		
				Sediment	Surface water	Fish
Dry	Pine River, MI (1999) DDT [2]	30,000 [2]	430,000 [2]	99 [2]	NA	NA
	Allied Paper, Bryant Mill Pond, MI (1998-1999) PCBs	150,000	21,000	99	NA	NA
	Ruck Pond, WI (1994) PCBs	7,700	785	NA	76	82
Wet	Sediment Management Unit 56/57, Fox River, WI (1999-2000) PCBs	81,700	2,111	59	NA	NA
	Deposit N, Fox River, WI (1998-1999) PCBs	8,200	111	12	NA	NA
	Ford.Monroe, MI (1997) PCBs	27,000	45,000	99	NA	NA
	GM, NY (1995) PCBs	13,800	9,300	99	NA	NA [3]
	Lake Jarnsjon, Sweden (1993-1994) PCBs	195,000	900	99	69	42
	Waukegan, IL (1992) PCBs	32,000	300,000	NA	NA	67 [4]
	Sheboygan, WI (demo) (1989-1990) PCBs	3,800	1,200	96 [5]	NA	NA [6]
	Shiawassee, MI (1982) PCBs	1,800	2,500	95	NA	82
ALL	Average reduction (sample size)	--	--	84 (N = 9)	72 (N=2)	68 (N=4)

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TABLE NOTES

NA: not available or not appropriate;

[1] Primary contaminants: PCBs polychlorinated biphenyls; DDT - dichloro-diphenyl-trichloroethane (old terminology).

[2] Information is for the first phase of cleanup addressing areas with highest DDT concentrations. DDT mass removed is based upon pre-dredging estimates. Final remedial activities are ongoing.

[3] New fish data is currently undergoing review.

[4] Waukegan: 14.1 ppm represent an average of composite sample collected and analyzed for 1983 and 1991 data (21, 32). 1978-1979 whole carp data averaged 24.1 ppm (15.2 ppm fillet equivalent, from ratio of fillet to whole body PCB concentration of 0.63 for carp from Little Lake Butte des Morts, Fox River, Wisconsin) 20, (21, 32).

[5] Sediments in areas dredged using a clamshell dredge were included in this evaluation.

[6] Surface water and fish data were not considered in this evaluation. This is because of ambiguity regarding their relevance to dredging effectiveness for this demonstration project. In addition to the dredging demonstration, there was also a contemporaneous capping demonstration, and there may still be additional contaminant sources that may be affecting surface water and fish monitoring results (4).

Table 2. Sediment Concentrations Completed Dredging Projects

Dredge Type	Project/Year/Primary Contaminants [1]	Average Sediment Concentrations			Cleanup Goals [2] Achieved? [ppm goal]	References[3]
		Pre-dredging (ppm)	Post-dredging			
			Post-dredging ppm	Concentration Percent reductions		
Dry	Pine River (Velsicol), MI (1999) DDT	3000	0.648	99	Yes [1 ppm]	8, 35
	Allied Paper/Bryant Mill Pond, MI (1998-1999) PCBs	110	0.46	99	Yes [1 ppm]	2, 26, 38
Wet	Sediment Management Unit 56/57, Fox River, WI (2000) PCBs	4.9 [4]	2.0	59	Yes [10 ppm]	39, 40, 41, 42
	Deposit N, Fox River, WI (1998-1999) PCBs	16	14	12	Yes [mass]	13
	Ford Monroe, MI (1997) PCBs	30,550	5	99	Yes [10 ppm]	7, 25, 34, 44
	GM Massena, NY (1995) PCBs	830	9 [5]	99	No [1 ppm]	15, 16
	Lake Jarnsjon, Sweden (1993-1994) PCBs	5	0.06	99	Yes [mass] [6]	5, 6, 9, 18
	Waukegan, IL (1992) PCBs	Maximum of 10,000	<50 [7]	NA	Yes [7] [50 ppm]	19, 20, 21
	Sheboygan, WI (demo) (1989-1990) PCBs	365 [8]	13 [8]	96	Demo project	3
	Shiawassee, MI (1982) PCBs	57	3	95	No [10 ppm]	24
ALL	Average reduction (sample size)	--	--	84 (9)	--	--

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TABLE NOTES

NA: not available;

[1] Primary contaminants: PCBs polychlorinated biphenyls; DDT - dichloro-diphenyl-trichloroethane (old terminology).

[2] Cleanup goals were most often concentration based. Three projects that had mass based goals were Ruck Pond (not listed on this table), Deposit N, and Lake Jarnsjon. The Sheboygan site was a demonstration project and did not have mass or concentration based cleanup goals.

[3] For cited references, please refer to Reference listing.

[4] Pre-dredging PCB concentration reported here is for surficial sediments prior to 1999 dredging (38). If all sediments depth intervals in the dredge area were considered, the pre-dredging average PCB concentration was 50 ppm (1), indicating a post-dredging concentration reduction of 98%. Also, prior to EPA 2000 dredging operations, "pre-dredging" surficial concentrations were an average of (coincidentally the same as 1999 predredging average concentrations for all intervals) 50 ppm (39).

[5] This concentration average includes an area that was subsequently capped. If capped areas were excluded, the average post-dredging concentration would be 5.2 ppm.

[6] The project goals for the Lake Jarnsjon project are not explicitly discussed in the cited references, but Bremle, 1998, (5) stated: "The remediation was successful in the sense that 97% of the estimated total amount of PCB in the sediment was deposited in the landfill."

[7] Cleanup goal of 50 ppm was determined by dredging design criteria to overdredge into the natural clean sand layer.

[8] Sediments in areas that were dredged using a clamshell dredge only were included in this calculation.

Table 3. Surface Water Concentrations for Completed Dredging Projects

Dredge Type	Project/Year/ Primary Contaminants[1]	Average Surface Water Concentrations			References[2]
		Pre-dredging (ppt)	Post-dredging (ppt)	Post-dredging Concentration Percent reduction	
Dry	Ruck Pond, WI (1994) PCBs	18	4	75	28
Wet	Lake Jarnsjon, Sweden (1993-94) PCBs	8.6	2.7	69	5, 18
All	Average reduction (sample size)	--	--	72 (2)	--

TABLE NOTES

[1] Primary contaminants: PCBs polychlorinated biphenyls; DDT - dichloro-diphenyl-trichloroethane (old terminology).

[2] For cited references, please refer to Reference listing.

Table 4. Fish Concentrations for Completed Dredging Projects

Dredge Type	Project/Year/Primary Contaminants [1]	Fish Concentrations [2]				References [3]
		Pre-dredging (ppm)	Post-dredging (ppm)	Post-dredging Fish Sampling Year(s)	Post-dredging Percent Reduction	
Dry	Ruck Pond, WI (1994) PCBs	23.5 [4]	4.2 [4]	1994	82 [4]	28
Wet	Lake Jarnsjon, Sweden (1993-94) PCBs	0.825 [5]	0.480 [5]	1996	42 [5]	5
	Waukegan, IL (1992) PCBs	14.7 [6]	4.7 [6]	1993-2000	68 [6]	22, 32
	Shiawassee, MI (1982) PCBs	14.6	2.6	1994	82	24
All	Average reduction (sample size)	--	--	--	68 (4)	--

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TABLE NOTES

NA: not available or not applicable;

[1] Primary contaminants: PCBs polychlorinated biphenyls; DDT - dichloro-diphenyl-trichloroethane (old terminology).

[2] Wet weight data.

[3] For cited references, please refer to Reference listing.

[4] Ruck Pond: Lipid normalized concentrations were -- pre-dredging: 17 mg/% lipid; post-dredging: 2 mg/% lipid; percent reduction 89%.

[5] Lake Jarnsjon: Lipid normalized concentrations were -- pre-dredging: 34 $\mu g\ g^{-1}$; post-dredging: 16 $\mu g\ g^{-1}$ giving post dredging percent reduction of 53% (slightly greater than not using lipid normalized data).

[6] Waukegan: 14.1 ppm represent an average of composite sample collected and analyzed for 1983 and 1991 data (20, 21). 1978-1979 whole carp data averaged 24.1 ppm (15.2 ppm fillet equivalent, from ratio of fillet to whole body PCB concentration of 0.63 for carp from Little Lake Butte des Morts, Fox River, Wisconsin) (20, 21, 32).

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