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US Army Corps of Engineers
Waterways Experiment Station

Dredging Operations and Environmental Research Program

Environmental Risk Assessment and Dredged Material Management: Issues and Application

Proceedings - Workshop 18-20 February 1998, San Diego Mission Valley Hilton, San Diego, California

by David W. Moore, Todd S. Bridges, Carlos Ruiz, WES

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Dick Peddicord, Dick Peddicord & Co., Inc.

Prepared for Headquarters, U.S. Army Corps of Engineers

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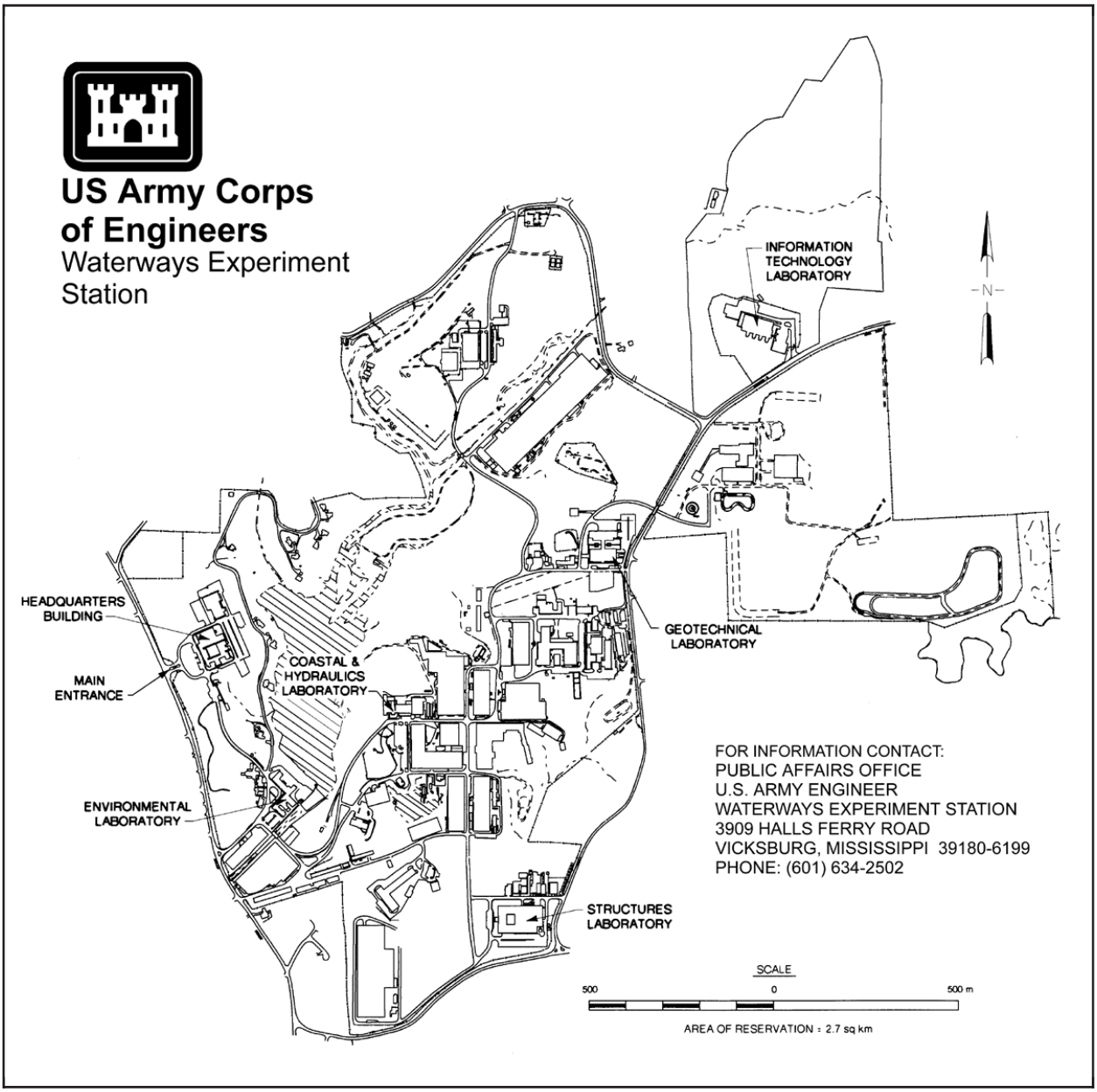

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U.S. Army Corps of Engineers Research Report Summary, December 1998
Dredging Operations and Environmental Research Program

Dredging: Contaminated Sediments

Environmental Risk Assessment and Dredged Material Management: Issues and Application (TR DOER-2)

ISSUES: Evaluating the potential environmental consequences associated with dredging and dredged material disposal is a difficult task. Scientific advancements have made possible the collection of large amounts of complex technical information. The dredged material manager must often weigh and balance multiple and sometimes conflicting lines of evidences to reach a decision; and each decision involves a certain level of uncertainty. The application of Environmental Risk Assessment methods will increase a manager's ability to make objective dredged material management decisions.

RESEARCH: A workshop entitled, "Environmental Risk Assessment and Dredged Material Management: Issues and Application" was held 18-20 February 1998 in San Diego, CA. The purpose of this workshop was to bring together expertise in the area of dredged material management and risk assessment to:

- Solicit input on risk assessment guidance being developed for the dredged material program.
- Identify important issues with regard to the application of risk assessment within the Corps' regulatory program.
- Identify areas for future research to improve upon the process.

SUMMARY: The workshop was attended by 78 invitees representing Corps field elements, other Federal agencies, industry, and academia. Participants represented a broad range of stakeholders and included permit applicants, dredged material managers, and risk assessors.

It was the general consensus of workshop participants that risk assessment should be used to augment and improve the dredged material management decision-making process. The importance of using risk-based approaches early in the evaluation process was emphasized. However, it was also noted that the current dredged material evaluation approach would be adequate for the vast majority of dredged material management decisions. Participants suggested that the greatest benefit of risk-based decision-making would be found by applying risk assessment in the smaller percentage of projects where there is high uncertainty regarding the potential for adverse environmental impacts. Recommendations generally fell into two categories: (a) procedural recommendations (ways to improve the dredged material decision-making process via incorporation of risk-based approaches); and (b) recommendations for improving existing assessment tools (models, tests, etc.) so that they can be used more effectively to make risk-based decisions.

AVAILABILITY OF REPORT: The report is available in .pdf format on the World Wide Web at http://www.wes.army.mil/el/dots and through Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, telephone (601) 634-2355. To purchase a copy of the report, call NTIS at (703) 4870-4780.

About the Authors: Drs. David W. Moore (formerly WES), Todd S. Bridges, and Carlos Ruiz (WES scientists) were the principal investigators for this research; contract support was provided by Drs. Jerry Cura, Susan Kane Driscoll, and Donna Vorhees, Menzie-Cura and Associates, Inc., Chelmsford, MA, and Dr. Dick Peddicord, Dick Peddicord & Co., Inc., Parkton, MD. **Point of Contact**: Dr. Todd S. Bridges, telephone (601) 634-3632 or e-mail *bridget@mail.wes.army.mil*.

Contents

Preface

The workshop summarized herein was entitled, "Environmental Risk Assessment and Dredged Material Management: Issues and Application." The workshop was held 18-20 February 1998 in San Diego, CA, at the San Diego Mission Valley Hilton. This effort was supported by Headquarters, U.S. Army Corps of Engineers (HQUSACE), through the Dredging Operations Environmental Research (DOER) Program. The DOER Program is managed at the U.S. Army Engineer Waterways Experiment Station (WES) by Mr. Clark McNair, Coastal Hydraulics Laboratory (CHL), Dredging Research Program, and Dr. Bob Engler, Environmental Laboratory (EL). HQUSACE program monitors are Messrs. Joe Wilson, Barry Holliday, John Bianco, and Charlie Chesnutt. This summary was prepared by compiling written summaries submitted by the co-chairman of three separate workgroups: Drs. Todd Bridges, Fate and Effects Branch (FEB), EL, WES, and Susan Kane Driscoll, Menzie-Cura and Associates, Inc., Chelmsford, MA, Effects Assessment Workgroup; Drs. Jerome Cura, Menzie-Cura and Associates, Inc., and Carlos Ruiz, Water Quality and Contaminant Modeling Branch (WQCMB), WES, Exposure Assessment Workgroup; and Drs. Dick Peddicord, Dick Peddicord & Co., Inc., Parkton, MD, and Donna Vorhees, Menzie-Cura and Associates, Inc., Risk Characterization Workgroup. This document does not represent the policy of the U.S. Army Corps of Engineers but is an accurate summary of the significant discussions occurring at the workshop.

This summary report was prepared by Drs. David W. Moore and Bridges, FEB, and Dr. Ruiz, Environmental Processes and Effects Division (EPED), EL, WES; Drs. Cura, Driscoll, and Vorhees, Menzie-Cura and Associates, Inc.; and Dr. Peddicord. Workshop logistics were managed by Ms. Freda Gibson, FEB, EPED, EL, WES. The organizers of this workshop acknowledge and thank all of the workshop participants for their valuable contributions to this important document.

The work described herein was performed under the general supervision at WES of Dr. Bobby L. Folsom, Jr., Chief, FEB. The Chief of EPED was Dr. Richard E. Price, and the Director of EL was Dr. John Harrison.

At the time of publication of this report, Commander of WES was COL Robin Cababa, EN.

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1 Introduction

Evaluating the potential environmental consequences associated with dredging and dredged material disposal is a difficult task. Scientific advancements have made possible the collection of large amounts of complex technical information. The dredged material manager must often rely on "best professional judgement" to weigh and balance among multiple and sometimes conflicting lines of evidence to reach a decision, and each decision involves a finite level of uncertainty.

In the current dredged material regulatory program, a tiered approach is used to reach a determination regarding the suitability of the material for aquatic disposal. This tiered approach provides for the efficient utilization of resources while ensuring that sufficient information is collected to make technically sound decisions. In each of the tiers, data are collected to assess the potential for exposure and effects. In the earlier tiers (Tiers I and II) existing information and simple screening tools are used, while in the later tiers more sophisticated effects-based laboratory bioassays are employed. In many cases, the interpretation of this information is fairly straightforward (e.g., toxicity was observed in an acute sediment toxicity test, therefore the material is unsuitable for aquatic disposal). However, in a smaller percentage of cases interpreting the significance of the information is more difficult (e.g., slightly elevated tissue concentrations of a chlorinated organic in a bioaccumulation test). In addition, concerns may arise that are not explicitly addressed within the existing tiered assessment framework (e.g., what is the risk to human health as a result of the potential trophic transfer of sediment associated contaminants to fish/shellfish species consumed by humans?). Questions such as these require a more thorough treatment of the information utilizing approaches and methods standard to environmental risk assessment. Environmental risk assessment provides a stepwise framework for the integration of complex information to yield quantifiable estimates of risk, including uncertainty. In addition, risk assessment allows the dredged material manager to make explicit the types of information considered and how a decision is reached regarding the suitability of a dredged material for a particular management option. It is important to note that much of the information necessary to conduct a risk assessment is already being collected within the existing regulatory program. How best to use this information and what tools are available for developing risk-based estimates and evaluating uncertainty for the dredging program were the focus of the workshop discussions reported herein.

The workshop was attended by 78 invitees representing Corps field elements, other Federal agencies, industry, and academia. Participants represented a broad range of stakeholders and included: permit applicants, dredged material managers, and risk assessors. A list of workshop participants and their affiliations is provided in Appendix A. The purpose of the workshop was threefold: (a) to solicit input from workshop participants on risk assessment guidance being developed for the dredged material program; (b) to identify important issues with regard to the application of risk assessment within the Corps' regulatory program; and (c) to identify areas for future research to improve upon the process. The first day of the workshop included a series of plenary talks encompassing a broad range of topics. The workshop agenda is provided in Appendix B. On the second and third days of the workshop, workgroups in the areas of effects assessment, exposure assessment, and risk characterization addressed important issues regarding the potential application of risk assessment in dredged material management and made specific recommendations to facilitate improved, cost-effective decision-making. A list of discussion items for consideration by each of the workgroups can be found in Appendix C. The significant discussions and recommendations of each of the workgroups are summarized in this report.

2 Exposure Assessment Workgroup Summary

Environmental risk assessments of dredged material management activities include an estimate of the potential for human and ecological exposures. The goal of the workgroup was to make recommendations for developing exposure assessments at these sites within the context of the current Technical Framework Document (U.S. Army Corps of Engineers (USACE)/U.S. Environmental Protection Agency (USEPA) 1992) and the sediment evaluation procedures (USACE/USEPA 1991, 1998). This section summarizes the exposure assessment workgroup discussions and recommendations.

When and Where should Risk Assessment be Applied?

Risk assessment should apply to only that small fraction of sites where application of the current procedures results in an uncertain decision. The consensus of the group was that the large majority of dredged material management decisions (estimated within the group as 95 percent) have an adequate degree of certainty within the existing approaches. However, among the remaining 5 percent, the decision-making process is so uncertain that it requires an integration of risk assessment within the technical framework and sediment evaluation procedures. Workgroup members felt that the USACE should map a pathway for using risk assessment which provides a consistent, documented, and fully accountable approach to remove or address the uncertainty inherent in these 5 percent of decisions.

The group also recommended that the risk assessment approach be implemented from the start of the planning process because it is often not possible to predict from the early tiers whether a site decision will require risk assessment. However, they cautioned against implementing risk assessment without explicitly recognizing its role in a site-specific, decision-making process. Specifically:

a. Risk assessment should be integrated into the current tiers without making sweeping changes to the existing procedures.

b. Research should not be incorporated into the assessments (because research efforts are uncertain by nature, and the cost should not be borne by a specific project).

c. An intuitive, common sense approach should be used to distinguish when to use a "back of the envelope" approach and when to use a "full" risk assessment.

d. Physical and chemical stressors should be addressed.

e. Stakeholders should be engaged as part of the initial assessment.

Defining Receptors and Hypotheses

The workgroup was mindful that the exposure assessment and the development of conceptual models could easily become a dilute repository for remote issues which do not pass the test of "reasonable concern." They felt that hypothesis testing and a clear definition of who or what we are trying to protect should drive the development of the exposure assessment. In particular, the identification of the protected entity was an ever-present concern guiding the workgroup discussions. The group noted that hypothesis testing and clearly defining the protected entity are important in constraining the exposure analysis, adding rationality to risk assessment, and in setting spatial and temporal limits for exposure models.

Likely Exposure Pathways in Dredged Material Management

The workgroup developed a matrix (Table 1) which summarizes our opinions regarding the likely exposure pathways for five commonly considered dredged material management options: Unconfined Aquatic Disposal, Subaqueous Confined Aquatic Disposal (CAD), Upland Disposal in a regulated landfill, Upland Confined Disposal Facilities (CDF), and the No-Action Alternative. This matrix indicates whether the pathway is a short- or long-term (S or L) concern for a particular alternative. Note that the matrix includes diffusion as a potential pathway, but the workgroup considered this pathway to be of minor or no concern based on information in the scientific literature.

There was particular concern with the fish ingestion pathway for humans and the development of ingestion rates. The general consensus was for using region-specific rates which incorporate the fraction of diet affected by a site. Exposure

Table 1
Most Likely Exposure Pathways For Five Dredged Material Management Options

Pathway	Unconfined	CAD	Upland	CDF	No Action
Volatilization			L	L	
Direct Ingestion (animal)	L		L	L	L
Resuspension/ Advection of Particles	L, S	S	S Dewatering	S Dewatering	L
Wind Transport			L		
Groundwater Advection (transport)	Unlikely	L	L	L	L
Diffusion	Literature shows unlikely significance (a)	Literature shows unlikely significance	Literature shows unlikely significance	Literature shows unlikely significance	Literature shows unlikely significance (a)
Dermal Contact (Animal)	L	S	L	L	L
Dermal Contact (Human)			L	L	L
Indirect Ingestion (human and animal)	L	S	L		

L = long-term concern; S = short-term concern; (a) Diffusion may be of some importance from the sediment bed to the water column under some conditions.

assessments should consider the local, ethnic dietary preferences and methods of food preparation. Recreational fishing habits may also be very important in considering diets. For example, some group members have anecdotally observed numerous recreational fishing boats at dredged material management sites on a year-round basis.

The group considered the use of caged animal studies to evaluate exposure pathways. There was a concern that stakeholders occasionally request or require such studies without a clear sense of how the results will be used in decision-making. The group felt that caged animal studies should not be considered a routine measurement method but may be useful in exposure assessment if:

a. There is reason to believe that pelagic exposure pathways are important.

b. They are done in a spatial and temporal series.

c. They are done in conjunction with fate and transport modeling.

Information Needs

The workgroup discussed the types of data necessary to conduct an exposure assessment, the applicability of current dredged material management site monitoring programs to fill these data needs, and the types of relevant data sources available outside the dredged material management program. The workgroup noted that the information needs for an exposure assessment are site- and project-specific. It is not necessary to consider all possible exposures but only those that appear reasonable within the context of protecting a specific organism or resource. The group also noted that these data needs will vary between dispersive and nondispersive sites.

With a clear sense of what should be protected, the collection of information useful to exposure assessment can begin in Tier I of the sediment evaluation procedures and early in the Site Designation Process for new sites. In moving through the tiers, it would be helpful if operations personnel had a checklist of the types of data that might be useful should a conceptual model and risk assessment become necessary. The group did not attempt to provide guidance as to what types of information might be needed under various site-specific conditions. Rather, we attempted to list the larger set of data needs, recognizing that a given site may require only a subset of these data categories.

There are three general categories of information useful in exposure assessment: biological characteristics, physical-chemical properties of sediment and surface water, and hydrodynamic characteristics. Again, consideration of a basic question, “What are the receptors?” dominated the development of a list of data needs. The important ecological receptors will be commercially important species, threatened or endangered species, recreationally important species, ecologically important species, and sensitive habitats.

Biological information needs. The group defined ecologically important species as keystone species whose presence in a system maintains a particular species composition, trophic structure, or physical environment. The sensitive habitats may include: sediment or water column areas which are important migratory routes, breeding grounds, or areas supporting sensitive life stages of a receptor; wetlands; or submerged aquatic vegetation. Recreationally important species are those which human populations use actively (e.g., a game fish population) or passively (e.g., bird watching).

The group listed explicit receptor characteristics which should be understood to develop an exposure assessment. These included: sensitive life stages; residence time near the dredged material management site; a summary of population dynamics; seasonal and annual variability in population abundance; a description of feeding relations; weight and age classes; length of exposure; lipid content; temporal and spatial scales of association with the dredged material management site; foraging area; migration patterns; feeding type; areal distribution; habitat requirements; and a description of the life cycle.

The workgroup concluded that there are four categories of human receptors who should be considered in the exposure assessment: (a) people drinking groundwater; (b) subsistence populations; (c) recreational fishers; and (d) consumers of commercial catches in the area of a dredged material management site. Perhaps the single most important data need for calculating risk to these potential receptors is a reliable fish ingestion rate based on local/regional dietary habits.

Physical and chemical information needs. The exposure assessment will also require information concerning the chemical and physical characteristics of the dredged material, much if not all of which is available in conducting Tiers I and II of the sediment evaluation procedures. The specific data needs include: sediment type, geochemical properties, total organic carbon, grain size, density, porosity, water content, and metal speciation. The group does not recommend the use of Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM), given the uncertainties associated with extrapolating from measurements made on an in-place sediment which will be dredged and placed in another location.

Terrestrial sites may require information on wind direction and transport, groundwater table fluctuations, groundwater flow, and soil properties (geochemistry, porosity, total organic carbon).

Hydrodynamic information needs. The exposure assessment must have information on the hydrodynamic characteristics of aquatic dredged material management sites. These include: current velocity, current depth profiles, net and gross deposition, the occurrence of resuspension, wave exposure, wind fetch, duration and direction, seasonal salinity and temperature profiles, occurrence of hypoxia, and suspended solids. Freshwater river systems will require information on high- and low-flow conditions, the occurrence of a spring freshet, and water levels. Marine systems will require a knowledge of local tidal ranges and currents.

Sources of Information

The workgroup expressed concern that the user community understand that the broad range of data needs does not suggest conducting a large-scale field data collection effort. There are often data sources readily available to provide most of the needed information in the exposure assessment. These data sources include the information gathered during the Site Designation, subsequent monitoring programs, and other databases. The Site Designation Process often requires the development of an Environmental Impact Statement which is a ready source of biological and physical characterizations of the dredged material management site. Obviously, this information may be dated for some, if not most, sites.

Most monitoring programs include only elevation and navigational hazard monitoring. Two exceptions are the Disposal Area Monitoring System (DAMOS) in New England which employs a tiered approach in which successive tiers use

more detailed testing upon reaching a contaminant concentration or biologically defined threshold. The sentinel area approach in the Pacific Northwest uses a similar tiered approach based on the occurrence of contaminants in predesignated "sentinel" areas surrounding a site. The routine monitoring done in these programs supplies some initial information on physical conditions at a dredged material management site (e.g., remote ecological monitoring of the seafloor system (REMOTS) sediment profiles, time series topography in the DAMOS program) and uses it to make decisions regarding the necessity for further testing (e.g., toxicity testing in the Puget Sound Dredged Disposal Analysis (PSDDA) program). The monitoring programs may include special studies such as: wave and current measurement programs at dispersive sites; benthic infauna abundance; measurement of infaunal tissue concentrations at the management site and in the near field; or measuring geotechnical parameters. However, in general, the monitoring programs do not answer the data needs of the exposure assessment.

The workgroup recognized that the USACE should provide the user community with a list of likely information sources which may include:

a. Resource agencies such as National Marine Fisheries Service, U.S. Fish and Wildlife Service, state agencies.

b. Stakeholder groups such as sport fishermen organizations, tribal groups.

c. Academic institutions, particularly those maintaining local field stations.

d. Literature reviews including identifying web sites.

e. Gray literature including Site Designation Reports, Bureau of Land Management and Minerals Management Service Reports, Fishery Reports, state Coastal Zone Management Plans, Fish and Wildlife Service Reports, National Estuary Program Comprehensive Management Reports, U.S. Environmental Protection Agency Wildlife Exposures Factors Handbook, National Pollutant Discharge Elimination System Permit Files; U.S. Geological Survey Reports, U.S. Coast Guard Reports, National Oceanic and Atmospheric Administration-National Ocean Survey Reports, U.S. Army Engineer Waterways Experiment Station Reports, U.S. Biological Survey Reports, Office of Naval Research satellite imagery, Department of Energy site conceptual exposure model software.

f. Technical points of contact.

Available Exposure Models

The more robust exposure assessments employed at relatively complex sites will probably rely on one or more food chain and/or fate and transport models. These are particularly important to integrate sediment physical-chemical

properties with site-specific biological characteristics or physical transport mechanisms. The models may be the only way to predict the potential fate of sediment contaminants or deposition of dredged materials and so will be critical for developing exposures at sites where dredged material management options are proposed.

Most of the discussion centered on the use of a food web model developed by Frank Gobas, which is now applied to the aquatic food webs of the Great Lakes, and the model first developed by John Connolly with versions now in use by Robert Thomann, HydroQual, Quantitative Environmental Analysis, CLC, and others. These predict the bioaccumulation of organic compounds. There appears to be a paucity of models within the open literature which predicts the fate of metals in food chains. One member of the group noted that the International Atomic Energy Agency (IAEA) has developed models which address the fate and transport of metals as part of their ocean disposal programs. The group felt that the USACE should explore the use of these models at dredged material management sites.

The models discussed included those which allow time-variable simulations and those which permit steady-state simulations. The two key differences between these are:

a. Time-variable simulation requires time-dependent exposure concentrations and physiological input information.

b. The analysis of model results is more complex for a time-variable simulation.

The choice between steady-state and time-variable applications of food web models depends on the availability of information regarding temporal variability of exposure concentrations and the physiological characteristics of the organisms, as well as on the specific questions addressed. If concentrations and conditions are changing slowly relative to the response time of the organisms, steady-state simulations may be appropriate. Six examples of situations under which time-variable simulations are appropriate follow:

a. Defining impacts of short-term, relatively large changes in exposure concentration due, for example, to a temporary release of a contaminant into the environment.

b. Defining response time of the biota to natural remediation or to remediation activities. This is especially important if more than one contaminant source contributes to the body burden of a species. For example, if a contaminant originates in the sediments and in ongoing sources to the water column, remediation activities may alter the relative importance of each source. A time-variable model allows one to track the changes in contaminant levels in the biota under these conditions.

c. Early life stages are often more sensitive to contaminants than older individuals. Full-life-cycle, time-variable models permit an analysis of how levels change during early life.

d. A time-variable model permits assessment of within-year variation in body burdens. Exposure concentrations, migratory behavior, growth rate, and lipid content may vary seasonally. Seasonal variation in body burdens may be of interest to aid in interpreting measured contaminant levels, depending on the timing of sample collections. It may also be of interest if planned activities (e.g., navigational dredging) occur at certain times of year.

e. In some ecosystems, bioaccumulation may be affected by the physiological condition of the organism. For example, the fat content of a fish species may change over time, perhaps due to changes in prey availability. This will cause the degree of bioaccumulation of hydrophobic organic contaminants to change over time. Such a change may affect the interpretation of temporal trends in fish contaminant levels.

f. Organisms integrate their exposure over time. This means that short-term variation in the level of a contaminant in fish may be much less than short-term variation in the water column. Water quality criteria are often expressed as the frequency of exceedance of a critical contaminant level. A time-variable model provides estimates of the frequency of exceedance in the presence of variable exposure levels.

Members of the workgroup felt that the uncertainty associated with the structure and parameterization of food web models for hydrophobic organic compounds are low relative to the uncertainty associated with the site-specific information required to perform site-specific simulations. One workgroup member noted that calculations of body burdens were within a factor of 3 with a 95 percent probability. The major sources of uncertainty tend to be the foraging area of the biota, the migratory behavior of the biota, dietary composition and food web structure, and exposure concentrations in sediment and water.

The workgroup addressed the issue of what factors need consideration in setting spatial and temporal scales within a model. Temporal scales are often set by the site recovery period and the recovery period of the biological community. Site recovery periods depend on processes such as biodegradation and burial of dredged material which occur in aquatic and terrestrial environments. The recovery of the biological community is usually a recovery from the physical placement of dredged material. Monitoring in the DAMOS program indicates two biological recovery periods in aquatic systems: a 1- to 3-month first-stage recovery due to colonization by opportunistic species; and, a 1- to 3-year end-stage recovery which involves a return to ambient biological communities. Model conditions generally address the end-stage receptors. The group noted that the first-stage recovery involves the exposure of ecologically different species from the end-stage organisms and that these opportunists encounter the “freshest” dredged

material. There was concern that this community and its exposures are not appropriately addressed.

Inherent physiological factors such as lipid synthesis and egg production or timing of the life cycle may also drive the temporal and spatial scales of the model.

Recommendations

The workgroup developed several recommendations concerning the conduct of exposure assessments at dredged material management sites. These include:

a. Clearly stated hypotheses and explicit statements of what the risk assessment is trying to protect should precede the development of an exposure conceptual model, the execution of any fate and transport or food chain model, or the conduct of any exposure test.

b. Early stakeholder involvement in the development of an exposure conceptual model should exist, and USACE and should specify where this should be done in the technical framework.

c. Attention should be focused on those exposure pathways which are the most likely contributors to risk for a given dredged material disposal alternative (Table 1).

d. The exposure conceptual model should be part of any routine monitoring program because it will help define data needs in the event the monitoring data reach a threshold requiring further investigation.

e. In most cases, the reasonable maximally exposed (RME) individual probably protects the sensitive fish-eating populations, but the exposure assessment should consider region-specific dietary information.

f. The tiered sediment evaluation procedure should incorporate a screening level exposure assessment early in the process, and this exposure assessment should be used in interpreting bioaccumulation testing.

Research Needs

The workgroup discussed and suggested the following research for further development of exposure assessments:

a. The trophic transfer potential of contaminants between early benthic colonizers and their predators must be established. The group noted that the potential for exposure to chemical contaminants early in the life of a

dredged material site is different when compared to later exposures due to the early presence of opportunistic species and their exposure to fresh material.

b. Far-field exposure models must be validated. Fate and transport models which predict particle transport and dissolved contaminant transport need field validation. This is particularly important in addressing the potential for off-site exposures from dispersive sites.

c. Food chain models that address exposures to metals must be developed or acquired. Other programs (e.g., IAEA) may have food chain models for metals. If so, the application of these to dredged material management sites should be explored.

d. A database on regional sources of information must be developed. The group recognized that much of the information necessary to do an exposure assessment is from sources other than the dredged material Technical Framework (USACE/USEPA 1992), sediment evaluation procedures (USACE/USEPA 1991, 1998), or Site Designation Reports. A database of information sources which describes the available categories of information and how to obtain them will conserve time and resources during development of the exposure assessment.

e. Protocols for the appropriate application and interpretation of in situ "caged animal" studies must be developed. The group felt that caged animal studies are a nonroutine measurement and that the USACE should develop a protocol regarding their use. The protocol should provide clear guidance on when such measurements may be helpful in addressing exposures and under what conditions they do not add to the development of the assessment.

f. Techniques for identifying and discriminating among different types of stress must be developed. There was concern that the exposure assessment should consider other sources of a particular stressor (such as contamination or changes to sediment grain size) which may be impacting chemical or physical conditions at the management sites. The USACE should develop or provide guidance for operations personnel to use in trying to discriminate among sources.

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3 Effects Assessment Workgroup Summary

Estimating the environmental effects associated with dredging is an important component of the dredging regulatory program. The Effects Workgroup focused its discussion on how risk assessment can be used within the framework of the dredged material management program to estimate environmental effects.

Determination of Toxicity and Unacceptable Risk

The Effects Workgroup discussed whether the occurrence of toxicity (significant and substantial mortality in sediment toxicity tests in comparison to reference), as defined under the Ocean Testing Manual (USACE/USEPA 1991) and the Inland Testing Manual (USACE/USEPA 1998), always equates to an unacceptable risk for placement of material at the disposal site. The consensus was that significant mortality in toxicity tests does not always equate to an unacceptable risk, because determination of risk must depend upon the size of the project, the nature of the contaminants, and the spatial and temporal aspects of the ecosystem features that we are trying to protect.

The workgroup noted that predictions of the effects of dredging and disposal are often based solely on the concentration and toxicity of contaminants in the material to be dredged, without consideration of the specific conditions at the disposal site. For example, the kinds and numbers of ecological receptors present at the disposal site and the actual potential for exposure of the receptors to contaminants from dredged material may be considered in the initial designation of a disposal site, but not when decisions are made about individual dredging projects. Also, the potential for photochemical and microbial degradation of contaminants, which can result in a decrease in the concentration of contaminants when dredged material is removed from the source of contamination, is not considered. The particular characteristics of the disposal site (e.g., types of receptors present at the site, types of potential exposure pathways) are not

considered in enough detail so that risk managers can make decisions about the potential for adverse ecological effects at the site.

The USACE is currently developing national guidance for incorporating environmental risk assessment into the dredged material management program. Participants of the Effects Workgroup expect that environmental risk assessment will be used when the results of standard biological tests are not definitive. For example, the suitability of a sediment for open ocean disposal depends upon whether results of toxicity and bioaccumulation tests are "significantly different" in dredged sediments in comparison to reference sediments. However, the amount of contaminant accumulated from a dredged material may be significantly greater than from reference sediments but too small to produce an adverse effect in exposed organisms. In an environmental risk assessment, the concentration of contaminant in tissue can be compared to concentrations previously shown to produce adverse effects. Thus, risk assessment allows managers to make better predictions about the potential for adverse effects associated with exposure to contaminated dredged material.

When, Where, and How to Use Risk Assessment

Considerable discussion revolved around when risk assessment should be used in the tiered evaluation process, and several views were expressed. Some members thought that risk assessment should replace the tiered framework. Other members thought that environmental risk assessment should not be used as a replacement for the present tiered evaluation of dredged materials (USACE/USEPA 1991) or as a replacement for biological testing. Rather, it should be used as an evaluation framework for interpreting data that are presently collected in standard toxicity and bioaccumulation tests. Some members felt that it should be used as the ultimate tier in difficult situations when lower levels have not provided a clear answer. Others thought that the tiered framework should be maintained, but that over time, the current tiered evaluation paradigm should gradually be replaced with risk assessment.

Members suggested that an ecological risk assessment framework could be developed as part of the disposal site designation process. The effects of individual dredging projects could be evaluated consistently by using a model risk assessment for the site. The workgroup discussed whether, for each contaminant of concern, a single risk-based criterion could be developed for the designated disposal site. Some members felt any risk-based criteria would have to account for the bioavailability of the contaminant in sediment. Bioavailability could be estimated by normalization of sediment concentrations to total organic carbon (TOC) or acid volatile sulfides (AVS) or measured with assays of bioaccumulation.

The implementation of a standard risk assessment model would address concerns expressed by members of the regulated community in the workgroup about the lack of consistency and predictability in the regulatory process from one

dredging project to another and from one region to another. It was suggested that a pending site designation in the New England district could be used to demonstrate the risk assessment process on a large-scale project. Ways to distribute the cost of developing a risk assessment framework among stakeholders were also discussed.

Participants noted the need for a demonstration project that would show concerned stakeholders how risk assessment can be used in the decision-making process. Participants also emphasized the need for having regulatory and stakeholder acceptance for the use of realistic site-specific risk assessments, as opposed to conservative screening-level assessments. Some members emphasized that stakeholders should reach an early agreement on what, specifically, they are trying to protect.

Several opinions were expressed concerning who would be responsible for conducting risk assessments in the dredging program. In one scenario, Federal employees would produce a model risk assessment for a particular site, perhaps as part of the environmental impact statement (EIS) for the site. Modifications to the model would be made in an assessment by the applicant, which would be reviewed by Federal employees.

Use of Numerical Effects Values

Numerical effects values are concentrations of contaminants in sediment that are expected to result in adverse effects on animals that inhabit the sediments. Various approaches have been used to develop these values. The equilibrium partitioning approach, which predicts effects of organic contaminants based on organic carbon normalized sediment concentrations, has been used to develop sediment quality action levels (USEPA 1993). Various empirical approaches are based on empirical analyses of data compiled from bioassays of field-collected samples, laboratory toxicity tests with spiked sediments, and benthic community analyses (Long et al. 1995; Long, Field, and MacDonald 1998; USACE/USEPA 1989). The participants of the Effects Workgroup generally agreed that numerical effects values should be used to constrain the assessment process, but no consensus was reached on how the numbers should be used.

Some participants felt that numerical effects values could be used to “pass” some sediments for open water disposal. For example, if managers and regulators agree that the rate of false negatives for the Effects-Range approach (11 to 13 percent, Long et al. 1995; Long, Field, and MacDonald 1998) is acceptable, the Effects-Range-Low (ERL) could be used to pass sediments. However, other participants noted that these effects levels do not take into account the potential for bioaccumulation and trophic transfer of contaminants. For example, some persistent organic compounds are not acutely toxic to benthic invertebrates, but are highly toxic to sensitive organisms at higher trophic levels.

Some members of the group suggested that the applicant be given the opportunity to accept a "failure" due to exceedance of numerical criteria and avoid the expense of biological testing, if there is no reasonable expectation of a biological test passing the material. The PSDDA Program has implemented such provisions in its dredging program. Other participants stated that numerical criteria should never be used alone to fail a sediment and exclude it from open water disposal. However, exceedance of the criteria could be considered as additional justification for the need for biological testing.

Sources of Uncertainty in Effects Assessment

The workgroup identified several important areas of uncertainty:

a. Lack of phylogenetic diversity in toxicity testing.

b. Uncertainty in extrapolating from effects measured in one test species to effects in a species of local concern.

c. Lack of standard approach for extrapolating from results of toxicity tests to population-level impacts.

d. Identification of appropriate species of concern.

e. Consideration of natural variability.

f. Lack of information about potential for chronic or sublethal toxicity.

g. Interpretation of bioaccumulation data.

Research Needs

The workgroup discussed and suggested the following research to further refine the manner of estimating the environmental effects associated with dredging:

a. **Compilation and interpretation of existing data**. Participants of the Effects Workgroup agreed that existing data and tools should be organized and made accessible to managers and applicants. Data from past dredging and monitoring projects should be analyzed, and the correlations between sediment chemistry (concentration of contaminants), toxicity in bioassays, and bioavailability of contaminants in bioaccumulation tests should be examined. Members of the regulated community noted that it might be useful for the applicant to have some ability to predict, on the basis of sediment chemistry, whether a particular sediment might exhibit significant toxicity and bioaccumulation in the standard tests and therefore be unsuitable for open water disposal. In that case, the applicant might

choose to forgo expensive biological testing and seek other disposal options. The USACE databases, such as the Environmental Residue-Effects Database (ERED), the Biota-sediment Accumulation Factor (BSAF) Database, and the Environmental Effects of Dredging Database (E2D2) are very useful compilations of information on dredged material (all these databases are accessible at http://www.wes.army.mil/el/dots). However, in some categories, a small fraction of the total data collected for dredging projects is entered into the database. For example, the number of BSAF entered into the database is a relatively small fraction of all of the data that have been collected in the dredging program.

b. **Field validation of existing or proposed biological tests**. The participants suggested that results of past field validation programs should be examined to determine whether adverse effects are occurring at disposal sites and whether biological tests are predictive of impacts at the site. In addition, the USACE and USEPA should consider new field validation programs at existing sites, e.g., the Historic Area Remediation Site (HARS) in New York/New Jersey, associated with the DAMOS in New England, or others.

c. **Interpretation of chronic, sublethal bioassays**. Participants noted that there is a need for developing guidance for interpreting the results of chronic, sublethal bioassays. For example, how should regulators make decisions based on significant reductions in growth of benthic invertebrates exposed to dredged material?

d. **Interpretation of ecological significance of bioaccumulation**. Participants of the workshop were given a demonstration of the Corps' ERED. This INTERNET-accessible database compiles and makes accessible information on tissue concentrations of contaminants that are associated with adverse biological effects, or in some cases, with no adverse effects. Participants of the Effects Workgroup found this to be a very useful tool for interpreting the significance of measured body burdens of particular contaminants. Participants noted that other groups, including USEPA, are also working on residue-effects databases. These groups should combine efforts. The workgroup expressed some concern about the level of knowledge that might be required to use information from the database appropriately. For example, effects in one phylogenetic group (e.g., molluscs) should not be used to estimate effects in a very different group (e.g., fish). The group concluded that a numeric threshold or criterion should not be established for any individual contaminant in the database.

e. **Predicting effects caused by mixtures of contaminants**. Contaminants that exert toxic effects by similar modes of action could produce effects that are synergistic or antagonistic. Assessments that examine the effect of each compound individually could underestimate or overestimate risk.

Participants noted that there is a need to develop and test approaches which can be used to predict the effects of mixtures.

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4 Risk Characterization Workgroup Summary

The Risk Characterization Workgroup discussed how risk assessment could be used to improve dredged material management decisions. The group considered when and how risk-based thinking and uncertainty analysis tools could be incorporated into permit decisions. These discussions resulted in a recommended risk-based decision framework. The framework calls for a level of analytic effort commensurate with the complexity of the decision to be made. The group also identified research priorities for improving the characterization of risk associated with dredged material operations and disposal.

Risk Assessment and Uncertainty Analysis in Dredged Material Management Decisions

The group reached a general consensus that risk assessment and uncertainty analysis should be an integral part of the dredged material management process. However, the group voiced many concerns regarding how this goal can be accomplished. These concerns may be summarized as follows:

a. Risk assessment may facilitate approval of a project that should not be approved.

b. Risk assessment may possibly delay decisions and add to project costs presumably due to additional time needed for analysis.

c. Acceptable levels of risk are difficult to define.

d. Risk assessment is undemocratic, because only experts understand it well.

e. The dredged material management decision process is adequate; therefore, there is no need to modify it.

f. Data requirements could be substantial.

g. It may be difficult to avoid making the mistakes that occurred using risk assessment under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

h. It is difficult to communicate results of risk analyses to the public, particularly in the case of politically volatile projects.

All of these discussions revealed skepticism among some workgroup members about how risk assessment can be used to better inform permitting officials and improve dredged material management decisions. Nevertheless, many of the concerns voiced by group members (e.g., substantial data requirements, difficulty in deciding on acceptable risk levels) exist whether or not risk assessment tools are used. The group's primary concern with using these tools seems to be the possible negative consequences of addressing uncertainty explicitly, especially for controversial projects with sparse data supporting permit decisions.

General Findings

The group agreed that risk assessment could be useful in dredged material management. One regulatory participant indicated that he is now making "pass/fail" decisions and would like to perform assessments that are more thorough. Another regulatory participant cautioned that he is "swimming in guidance documents" and that any new risk assessment guidance should be concise and general enough to allow for modification by local officials. Many recognized that risk assessment is already an integral part of the USACE four-tiered technical framework and that most projects do not require extensive risk analysis. Rather, such analysis would be needed only for complicated projects that comprise a small percentage of proposed projects. In light of these findings, the group sought to develop a defensible and efficient decision-making framework that would be compatible with the existing framework.

The group acknowledged that uncertainty is a critical element of risk assessment, but that Federal and state regulators do not generally understand how uncertainty analysis can be used in dredged material management. For example, it can help regulators characterize spatial and temporal variability of dredged material management impacts. Identification of such variability can be a key to comparing potential impacts of different dredged material management alternatives. Ideally, uncertainty analysis could illuminate the continuum between possible decisions and the consequences of those decisions. USACE and USEPA personnel must be trained in how to use these tools within the existing regulatory structure and budgetary constraints.

Many expressed concern with how risk can be communicated effectively to the public and identified the need for case studies where such communication has occurred successfully. Some pointed out the importance of including members of the public in the risk assessment process rather than simply reporting the conclusions of such an assessment to them.

One participant proposed that regulators reject permit applications and require submission of additional information or reconsideration of projects when the potential for adverse effects is very uncertain. Others responded that the applicant might have limited flexibility for reconsidering the project.

One group member recommended that the USACE recognize the social ecology surrounding dredged material management project controversies. Specifically, human value judgments about ecology are the focus of dredged material management decisions and could prevent objective management of cumulative risk. For example, a disposal option might be rejected simply because it is located in close proximity to people, even if it has the least potential to cause adverse human health and ecological impacts.

Research Needs

Workgroup members were asked to recommend research initiatives to eliminate large contributors to uncertainty in the risk characterization of dredged material management alternatives. Their major research request was to report on case studies that demonstrate how risk assessment and uncertainty analysis could aid regulatory decision-making, research planning, and risk communication. Other important recommendations are listed below in no particular order:

a. Expand on existing centralized research databases (e.g., ERED) and create new centralized databases.

b. Conduct new research to derive tissue effect levels.

c. Monitor environmental effects of dredged material management activities and compare to predictions of effects (e.g., compare trophic transfer data to model results).

d. Determine innovative ways to quantify risk at dispersive versus non-dispersive sites.

e. Gather life-cycle information to aid in the interpretation of BSAF and the extrapolation of BSAF across taxa.

f. Improve understanding of basis for extrapolating from laboratory to field conditions, including extrapolations from lab species to native species, from individual indicator species to populations.

g. Investigate efforts of others to develop ecosystem models (i.e., models that illustrate relationships among species).

Recommendations

The research recommendations of the workgroup are ambitious, and perfect information will never be available. Recognizing this dilemma, workgroup members developed practical, short-term recommendations for improving risk characterization of dredged material management projects. Figure 1 depicts a risk-based framework proposed by the workgroup for integration into the existing USACE four-tier framework. It begins with conservative screening phases followed by increasingly complex levels of analysis. Screening steps include use of sediment quality values that should be used only for screening, not for risk estimation. Regulators must be explicit about the uncertainty in identifying and using sediment quality values and other benchmarks. Higher phases, reserved for complex projects, should include use of probabilistic methods. More work is needed to integrate the proposed framework into the existing USACE framework. The working group recommends that the USACE field staff be instrumental in performing this task, consulting with risk assessors to complete the task.

Early framework phases could be automated after the USACE considers how risk assessment could augment the less complex decisions that the USACE staff must make. Interested individuals and groups should be included in this process. No criteria were developed for advancing to higher phases; however, the group recommended that analytical and remedial costs should be balanced against expected reductions in risk.

The risk assessment framework should be used and sources of uncertainty made transparent for physical and chemical effects of dredged material operations and disposal. Risk assessment must be consistently applied, not used just when permitting decisions have become controversial. However, uncertainty tools are most useful when there is a great deal of uncertainty about potential risk and less useful when there is clearly very low risk or very high risk. One beneficial use of risk assessment and probabilistic analysis would be to segregate sediment that requires special management from sediment that does not require special management.

To fulfill these recommendations, the USACE should initiate training of field staff in ecological risk assessment of dredging operations and analytic tools for evaluating uncertainty. This training should distinguish between risk assessment for cleanup dredging and for navigation dredging.

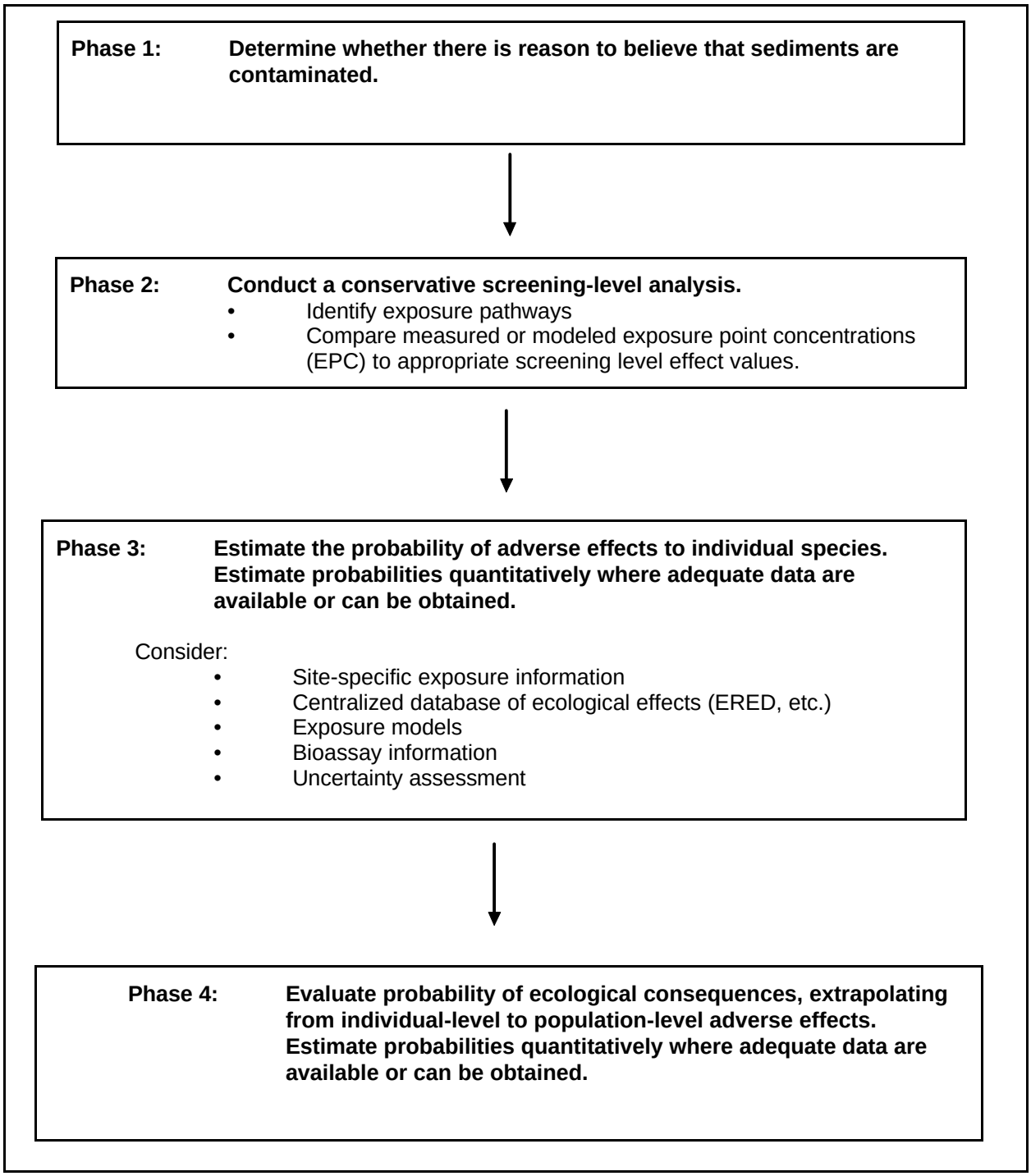

Figure 1. Risk-based decision framework for dredged material management. At the conclusion of each phase, the regulator advances to the next phase if insufficient information is available to reach a determination

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5 Summary

It was the general consensus of workshop participants that risk assessment should be used to augment and improve the dredged material management decision-making process. The importance of using risk-based approaches early on in the current tiered assessment scheme was emphasized. However, it was also noted that the current dredged material evaluation scheme as outlined in the Ocean and Inland Testing Manuals (USACE/USEPA 1991, 1998) was adequate for the vast majority of dredged material management decisions (estimated by some participants to be 95 percent). Participants suggested that the greatest benefit of risk-based decision-making would be found by applying risk assessment in the smaller percentage of projects where there is high uncertainty (e.g., no evidence of acute toxicity but some elevated bioaccumulation of contaminants). Recommendations generally fell into two categories: (a) procedural recommendations (ways to improve the dredged material decision-making process via incorporation of risk-based approaches) and (b) recommendations for improving existing assessment tools (models, tests, etc.) so that they can be used more effectively to make risk-based decisions. Specific recommendations included:

a. All dredged material evaluations must be preceded by clearly stated hypotheses and explicit statements of what is to be protected.

b. All dredged material evaluations should include early stakeholder involvement, especially in the development of the conceptual model.

c. Conceptual exposure models should be used to define and develop monitoring programs for dredged material disposal sites.

d. Databases on regional sources of information (e.g., region-specific dietary information for evaluating exposure, data from past dredging projects) must be developed to ensure consistency/accuracy and reduce cost of risk-based evaluations of dredged material.

e. Screening-level exposure assessment should be used early in risk-based evaluations of dredged material to focus limited resources on high priority issues.

f. Existing and proposed biological tests must be field validated to ensure ecological relevance.

g. Existing centralized databases (e.g., ERED and the BSAF database) must be maintained and expanded.

h. Procedures for extrapolation of data (e.g., BSAF information across taxa; benchmark species to native species; individual- to population-level effects, etc.) must be developed and standardized.

i. Better information/approaches for estimating the trophic transfer potential of contaminants especially for metals must be developed.

j. Far-field exposure models must be validated.

k. Protocols for the appropriate application of in situ studies and guidance for how such approaches should be used to improve estimates of exposure must be developed.

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Appendix B
Workshop Agenda

AGENDA FOR RISK WORKSHOP
17-20 February, 1998
San Diego Mission Valley Hilton, San Diego, CA

Tuesday (17 February) Workshop participants arrive

Wednesday 8:00-11:30 - Morning Plenary

8:00-8:10	Introductory remarks (Dr. David Moore)
8:10-8:40	Overview of the Technical Framework in the Evaluation of Dredged Material Disposal Options (Dr. Michael Palermo)
8:40-9:10	Overview of the Tiered Assessment Framework for Aquatic Disposal (Dr. David Moore)
9:10-9:40	Overview of Preliminary Risk Guidance (Dr. Jerry Cura)
9:40-10:10	Coffee Break
10:10-10:40	"Ecological Risk Assessment of Contaminated Sediments: Navigational Dredging" an overview of the SETAC Pellston Workshop (Dr. Dick Peddicord)
10:40-11:10	Case Study: "Grays Harbor" (Mr. John Wakeman)
11:10-11:40	Case Study: "NY/NJ Harbor Dredged Material Management Plan Screening Level Risk Assessment" (Dr. Susan Kane Driscolll)
11:40-1:00	Lunch
1:00-1:30	"Sediment quality values (SQVs) and ecological risk assessment (ERA)" (Dr. Peter Chapman)
1:30-2:00	Exposure assessment - "Trophic Transfer in Aquatic Env." (Dr. Frank Gobas)
2:00-2:30	Exposure assessment - "Trophic Transfer to Avian Species" (Dr. David Glaser)

2:30-2:40	Break
2:40-3:10	Effects assessment- “Interpreting Bioaccumulation” (ERED) (Dr. Todd Bridges)
3:10-3:40	“Dredged Material Management: Major Contributors to Uncertainty in Risk Estimates” (Dr. Donna Vorhees)
3:40-4:10	“Probabilistic Approaches” (Dr. Dwayne Moore)
4:10-4:40	“Probabilistic ecotoxicology at the population level: Case studies illustrating what we know and what we don't know” (Dr. Scott Ferson)
4:40-5:00	Closing Remarks (Dr. David Moore)
5:00-5:30	Participants divide into workgroups and given workgroup charge

- WG 1 - Exposure Assessment
- WG 2 - Effects Assessment
- WG 3 - Risk Characterization

5:30-7:00 Informal Reception

Thursday 8:00 - 11:30 - Workgroup Breakouts

- WG 1 - Exposure Assessment (Co-Chairs- Drs. Cura & Ruiz)
- WG 2 - Effects Assessment (Co-Chairs- Drs. Kane Driscoll & Bridges)
- WG 3 - Risk Characterization and Uncertainty (Co-Chairs- Drs. Vorhees & Peddicord)

Thursday 1:00 -5:30 - Workgroup Breakouts (Cont.)

- WG 1 - Exposure Assessment
- WG 2 - Effects Assessment
- WG 3 - Risk Characterization and Uncertainty

Friday 8:00 - 11:00 - Workgroup Summary Reports

- WG 1 - Exposure Assessment
- WG 2 - Effects Assessment
- WG 3 - Risk Characterization and Uncertainty

Friday 11:00 - 12:00 - Workshop Summary

- Issues & Future Directions

Appendix C
Discussion Items

General Questions to be Addressed by All Workgroups

a. How should information attained from the Army Corps' tiered testing framework be used in a risk assessment?

b. When should risk assessment be used within the tiered assessment framework?

c. Who will perform risk assessments on dredged material management projects?

d. What are the limitations to conducting a risk assessment that is not site specific (e.g., How can one use risk to rank management alternatives prior to site selection)?

Exposure Assessment Workgroup

a. What are the important fate and transport pathways associated with different disposal alternatives? What physical fate and transport models can be used to model these pathways? Do the models predict concentrations in ambient water and sediment?

b. Describe monitoring occurring at dredged material disposal sites (i.e., What types of physical, chemical, and biological data are being collected at these sites?)

c. What other types of information could be collected during dredged material evaluations to better facilitate evaluation of fate and transport mechanisms (e.g., Since concentrations of dissolved organic carbon (DOC) in ambient waters can affect concentrations of freely dissolved organic contaminants

and associated bioavailability, should DOC be routinely measured in elutriate tests or in ambient waters at disposal sites? What about acid volatile sulfide in sediments)?

d. What models are available for predicting food chain transfer and biomagnification in higher trophic level organisms in aquatic and terrestrial ecosystems?

e. How reliable and useful are the available food chain models? What uncertainties are associated with models of trophic transfer?

f. What are the advantages and disadvantages of the various approaches? For example, how different are the predictions of the physiologically based Gobas model in comparison to the Great Lakes Water Quality Initiative approach which uses steady-state bioaccumulation factors (BAF) to predict fish tissue concentrations from water concentrations? Are the results from different approaches comparable?

g. Should 28-day body burden data be corrected for hydrophobic compounds that are not expected to reach steady state in 28 days? How should steady state for metals be addressed?

h. What are the largest sources of uncertainty in exposure assessment? How can these uncertainties be reduced? How should these uncertainties be characterized?

i. What are the appropriate temporal and spatial scales to characterize exposure of dredged material management options?

j. How important is it to attain site-specific estimates of fish ingestion rates for human health risk assessments? Is it important to incorporate information on methods of food preparation?

k. What are the important areas for future research in exposure assessment?

Effects Assessment Workgroup

a. How reliable are the World Health Organization's 2,3,7,8-dioxin Toxic Equivalency Factors (TEF) for fish, birds, and mammals?

b. What are the appropriate sources of data on toxicity?

c. How should the U.S. Army Corps of Engineers' Environmental Residue-Effects Database (ERED) be used in effects assessment? For example, in the absence of information on the species of interest, should minimum or average residue-effects be used for comparison to test data sets?

d. How should effects of endocrine disruptors be considered or tested?

e. Does the occurrence of toxicity as defined under the Ocean and Inland Testing Manuals (USACE/USEPA 1991, 1998)[1] always equate to unacceptable risk?

f. What are the important data gaps in ecological toxicity data? Are there species that are particularly important at dredged disposal sites for which no information is available?

g. What criteria should be used to select receptors (human and eco) at greatest risk at various dredged material disposal sites? How can risks to these receptors be minimized through appropriate site selection?

h. What are the most important sources of uncertainty in effects assessment? How can these uncertainties be reduced? How can these uncertainties be characterized?

i. Is there evidence for adverse effects on human and ecological receptors as a result of dredged material disposal?

j. Should risk assessors account for the speciation of metals in environmental samples (e.g., chromium or arsenic)?

k. What are the appropriate temporal and spatial scales for characterizing effects?

l. What are the important areas for future research in effects assessment?

Risk Characterization Workgroup

a. Should Hazard Quotients be modified to express risk? What alternatives are available?

b. When should weight-of-evidence approach be used in risk characterizations? What approaches are useful?

c. What is the appropriate role of uncertainty analysis in assessing risk (human or ecological) associated with dredged material management? What tools are available to characterize uncertainty and when is it most appropriate to use these various tools?

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[1] Reference information follows main text.

d. Where/when has uncertainty analysis been used before in the context of dredged material management? What benefits were attained by using uncertainty analysis?

e. What are the appropriate temporal and spatial scales for characterizing risks associated with dredged material management?

f. How should 'reference' (as defined in the Ocean and Inland Testing Manuals (USACE/USEPA 1991, 1998)) be used to assess risk experienced by higher trophic organisms at dredged material disposal sites? How can we determine if risk at a dredged material disposal site is significantly greater than risk at a reference site?

g. What are important areas for future research? For example, which sources of uncertainty have the greatest influence on decision-making? Is it possible to reduce these areas of uncertainty? How should this uncertainty be described or characterized?

h. How should bioaccumulation data be used in ecological or human health risk assessments? For example, can body burdens measured in 28-day bioaccumulation tests with the clam, *Macoma balthica*, be used as surrogates for species that are consumed by humans? Should we be testing species that people actually consume?

i. What is the role of comparative risk assessment in making management decisions?

j. How can one conduct a comparative risk evaluation of dredged material management options (e.g., Subaqueous Confined Aquatic Disposal (CAD) vs. Aquatic; Aquatic vs. Upland Confined Disposal Facilities (CDF))? What are the limitations?

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13. ABSTRACT *(Maximum 200 words)*

Evaluating the potential environmental consequences associated with dredging and dredged material disposal is a difficult task. Scientific advancements have made possible the collection of large amounts of complex technical information. The dredged material manager must often rely on “best professional judgement” to weigh and balance among multiple and sometimes conflicting lines of evidence to reach a decision, and each decision involves a finite level of uncertainty. How best to utilize this complex technical information and what tools are available for developing risk-based estimates and evaluating uncertainty for the dredging program were the focus of the workshop discussions reported herein.

The workshop was attended by 78 invitees representing Corps field elements, other Federal agencies, industry, and academia. Participants represented a broad range of stakeholders and included permit applicants, dredged material managers, and risk assessors.

It was the general consensus of workshop participants that risk assessment should should be used to augment and improve the dredged material management decision-making process. The importance of using risk-based approaches early on in the current tiered assessment scheme was emphasized. However, it was also noted that the current dredged material evaluation scheme as outlined in the Ocean and Inland Testing Manuals was adequate for the vast majority of dredged material management decisions (estimated by some participants to be 95 percent). Participants suggested that the greatest benefit of risk-based decision-making would be found by applying risk assessment in the smaller percentage of projects where there is

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high uncertainty (e.g., no evidence of acute toxicity but some elevated bioaccumulation of contaminants). Recommendations generally fell into two categories: (a) procedural recommendations (ways to improve the dredged material decision-making process via incorporation of risk-based approaches) and (b) recommendations for improving existing assessment tools (models, tests, etc.) so that they can be used more effectively to make risk-based decisions. Specific recommendations are included in the final chapter.