ENVIRONMENTAL IMPACT OF DREDGING, DREDGED MATERIAL DISPOSAL, AND DREDGED MATERIAL RESEARCH IN THE US

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Each year approximately 400,000,000 cubic yards of sediment are dredged from US waterways in order to maintain the desired navigation depth. Prior to about 1970, these dredged sediments, frequently called spoil, were disposed of in the most economical manner, in nearby waterways or on nearby land. In the late 1960's, state and federal pollution control agencies became increasingly concerned about the environmental impact of dredged material disposal. Particular attention was focused on the significance of chemical contaminants associated with dredged sediments. The primary purpose of this paper is to review the current research needs regarding environmental impact of dredging and dredged material disposal. Particular attention will be given to the significance of chemical contaminants associated with dredged sediments and especially to those contaminants that have caused development of a series of regulations governing dredged material disposal in the US during the past six years.

Before discussing research needs, it is appropriate to review legislation and regulations that have been and are currently applicable to determining where a particular dredged sediment may be deposited. This review sets the stage for discussion of research needs since the current and pending regulations govern the approach that must be taken in assessing the environmental impact of dredged material disposal.

No attempt has been made to focus on all of the various legislative acts that regulate dredged material disposal. Such comprehensive reviews were recently presented at the Mobile, Alabama ASCE Specialty Conference on "Dredging and Its Environmental Effects" and will appear in the proceedings of that conference.

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Discussion of research needs in this paper is intended to focus on large-scale needs and not review some of the highly important specific needs associated with certain aspects of dredged material disposal. Many of these have been reviewed in papers and reports by the author (See References).

Previous Criteria for Dredged Material Disposal

In the late 1960's, the US Army Corps of Engineers Buffalo District, at the request of Federal Water Quality Administration (FWQA) initiated studies on the pollutional characteristics of sediments taken from selected Great Lakes harbors. These studies showed that, based on the classical parameters used to characterize the pollutional tendencies of municipal and industrial wastes, many of the Great Lakes harbor sediments were grossly polluted.

As a result, the FWQA proposed what are frequently called the "Jensen Criteria" for dredged material disposal. These criteria specified the maximum amounts of volatile solids, COD, total Kjeldahl nitrogen, oil and grease, mercury, lead and zinc that would be permitted in the dredged sediments that were to be disposed of in US waters. These criteria were adopted by the FWQA in about 1970, and although to a major extent were based on Great Lakes sediments, were made applicable to all US waters, both fresh and marine. These criteria were based on bulk chemical composition of dredged sediments. No attempt was made by the FWQA to determine what the potentially significant available fraction was for the chemical constituents on which limits were set.

In 1971 the FWQA had the Corps of Engineers issue Engineering Circular 1165-2-97 which stated that under Section 10 of the 1899 Refuse Act, the "Jensen Criteria" should be applicable to sediments dredged from all US waters. Promulgation of these criteria resulted in a massive analytical effort in which sediments from throughout the US were tested for these parameters. Based on the results of these tests, sediments were classified as polluted if

the concentrations of any of the parameters exceeded the criterion limit.

These criteria resulted in a significant immediate impact on dredged material disposal throughout the US. Sediments from waterways throughout the country were classified as polluted and in many instances alternate methods of dredged material disposal had to be found. Generally, the alternate methods involved either transport over great distances for open water disposal or deposition on land in confined disposal areas. In some areas where no land was available, dikes were constructed in the water and deposition took place behind these dikes. With few exceptions the majority of the on land disposal systems involved overflow of the supernatant liquid to the nearby water course. Particular attention at this time was being given to developing a diked disposal system for "polluted" Great Lakes harbor sediments. The Rivers and Harbors Act of 1970 Public Law 91-611, Section 123 (i) provided for the initiation of a ten-year diking program for polluted sediments. Again, the "Jensen Criteria" were used as a basis by which sediments should be classified as polluted or non-polluted.

In May 1971, as part of PL 91-611, the Corps of Engineers was authorized to initiate a comprehensive evaluation of the environmental impact of dredged material disposal. This study is being conducted at the Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi. The results of Phase I, Problem Definition and Assessment, was published as a report by Boyd et al. (1)

The Boyd et al. (1) review of dredging and dredged material disposal practices in the US resulted in the specific recommendation of a five-year comprehensive study of the environmental impact of dredged material disposal. This study was approved by OMB for a tentative total funding of approximately $30,000,000 to be spent over the five-year period. Conduct of this study was

assigned to the Corps of Engineers Waterways Experiment Station (WES) at Vicksburg, Mississippi. This study, initiated at WES in March, 1973, has become known as the Dredged Material Research Program (DMRP).

The DMRP is divided into four project areas which are

1) Environmental impact and criteria development,
2) Habitat development research,
3) Disposal operations research, and
4) Productive uses research.

The Second Annual Report of the DMRP (2) provides a good overview of the various studies that have been conducted under each of these project areas.

In October, 1973, under the authorization provided in PL 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972), the US EPA developed guidelines for ocean disposal of dredged material. In the fall of 1975 under the authorization provided in PL 92-500 (Federal Water Pollution Control Act Amendments of 1972), the US EPA promulgated "interim final" dredged material disposal criteria for the freshwaters of the US.

Economic Impact of Bulk Chemical Criteria

From the first promulgation of the "Jensen criteria" until today there has been chaos associated with dredging and dredged material disposal throughout the US. Normally approximately $200,000,000 is spent each year on dredging US waterways. For FY 75 the expenditure was $232,000,000; for FY 76 it is estimated to be $241,000,000. Moreover, the unit cost of dredging has increased significantly during the past several years. For FY 75 the unit cost was 70 cents per cubic yard. The unit cost is highly dependent on the relative proportions of new work dredging, i.e., dredging an area for the first time, and maintenance dredging, i.e., dredging to a certain depth in an area that has been previously dredged. Unit costs of dredging range from 30 to 40 cents per cubic

yard in some areas where large amounts of material are moved relatively short distances (such as near the mouth of the Mississippi and along the Texas Coast) to the several dollars per cubic yard æssociated with the dredging of small harbors such as those in New England. In the Great Lakes region it typically runs $1.50 to $2.00 per cubic yard today.

Lee (3) reviewed the additional cost of dredging and dredged material disposal which could be attributed to alternate methods of disposal adopted when sediments were classified as polluted by the FWQA's bulk sediment ("Jensen") criteria. He found that the environmental regulations had little or no effect on the costs of dredged material disposal in some parts of the US. In other areas, however, the effect had been quite pronounced. At several places in the US, environmental considerations have made the cost of dredged material disposal and thus dredging prohibitive. The harbors and waterways are silting in and eventually will become unnavigable.

Lee found, based on discussions with various Corps of Engineers districts, that typical increased costs associated with potential environmental impact of chemicals associated with the dredged sediments are in the order of 10 to 20 percent. The dramatic increases in fuel and labor costs that have occurred during the past two years will cause this percentage to increase even further, since, with few exceptions, the alternate methods of disposal would require greater fuel consumption and greater labor costs.

Of greater significance is the fact that some dredging projects which were originally scheduled to be conducted during the past year are being delayed because of potential environmental impact associated with chemical contaminants present in the sediments. In some areas this means that ships have to be partially unloaded in deeper water in order to lessen draft so that they can reach the port. Further, any delay results in a significant increase in cost because of inflation. The total cost of this situation is impossible to assess accurately.

One of the basic questions that must be resolved at this time is whether the approach that was adopted as a result of the FWQA

promulgating the "Jensen criteria" was technically, economically and ecologically sound. In the opinion of many, including the author, it was not justifiable based on the information available at the time the FWQA first promulgated these criteria nor is it justifiable based on information available today. Their adoption clearly appears to have been a case of overreaction associated with the Earth Day movement that swept the country in the late 1960's and early 1970's. It is true that chemical contaminants are found in dredged sediments. However, as discussed by Lee and Plumb (4) and Lee et al. (5), the increased funds for environmental quality control associated with chemical contaminants in dredged sediments may have been of little or no ecological significance in many parts of the country. Moreover, in some areas the alternate methods of disposal, such as on land disposal in diked areas with overflow to the nearshore waters, may have been more detrimental to the aquatic ecosystems than the open water disposal techniques that had been used prior to 1970.

Background Information on Significance of Chemical Contaminants in Dredged Sediments

Judging from the actions taken by some water pollution control regulatory agencies for dredged material disposal, there should have been several documented cases of chemical contaminants associated with dredged sediments having had a significant adverse effect on water quality at the disposal site. Often representatives of activist groups and in some instances pollution control agencies will make statements to the public or before congressional or legislative hearings that disposal of dredged sediments which contain certain contaminants has been found to have a certain adverse effect on a particular ecosystem in association with open water disposal, yet when one reviews the basis for the statements, he finds that as of yet there has been no documented case where contaminants present in dredged sediments have had a significant adverse effect on aquatic ecosystems as a result of open water disposal. This situation should

not lead one to complacency. It cannot be assumed that in every situation the contaminants present in dredged sediments will be harmless when disposed of in open waters or when put into a confined disposal area with supernatant overflow to the nearby water course or underflow to the groundwater. Certainly there will be some situations where these contaminants will not be completely deactivated by association with the dredged sediment and could have a significant adverse effect. It is therefore imperative that procedures be developed which could screen out these situations and allow a special approach to be taken for them.

Some Corps of Engineers districts have spent large amounts of funds on research on the environmental impact of dredged material disposal in which it was assumed that there was a problem. This was caused by environmental activist groups who stated that there was a problem; however, when one examined the situation critically, it was found that the likelihood of a significant problem was extremely remote. Under these circumstances, rather than conducting massive research programs designed to try to solve a problem that does not exist, funds should be devoted to trying to define the real problems associated with chemical contaminants in dredged sediments. The focus should be directed toward how this potential problem can be evaluated and minimized.

It is important to emphasize that the question is not one of whether contaminants in sediments can have an adverse effect. Certainly this occurs under certain circumstances. The basic question is whether the process of dredging and dredged material disposal in open waters can have a significant adverse effect on water quality at the disposal site.

Some reason that if one is to err with respect to the environment, he should err on the conservative side. It can be argued that utilizing the usually costlier alternative methods of disposal is the conservative approach and well worth the additional cost to protect the environment. This, however, is not a valid argument for dredged material disposal as normally practiced today. Usually,

when the materials are deposited on land, the supernatant liquid is allowed to flow into nearshore waters where there is usually less mixing and more sensitive aquatic species and forms than are found in open waters. As discussed in detail by Lee (3) and Lee et al. (5), these alternate disposal methods may be more detrimental to aquatic ecosystems than the previously used methods.

In defense of a conservative approach, there is every reason to believe that in some instances the disposal of contaminated sediments may be adverse to water quality at the disposal site. Therefore, what is needed is a procedure by which the potential significance of chemical contaminants in dredged sediments can be assessed prior to dredged material disposal. This would ensure that the large amounts of chemical contaminants associated with some dredged sediments are not significantly adverse to aquatic life at the dredged material disposal site.

Overview of Current Research on Significance of Environmental Impact of Dredged Material Disposal

There is evidence that under certain conditions, disposal of dredged sediments (independent of chemical composition) can be adverse to aquatic life, particularly benthic organisms at the disposal site. This is related to the problems of burying of organisms and changes in the characteristics of the bottom. This kind of problem must be approached differently from that associated with chemical contaminants in dredged sediments.

It is also clear that the decision by OMB to support a major research effort in this area is justified because it could provide the information needed to determine what is the actual effect of dredging and dredged material disposal on environmental quality. From a strictly economic point of view, if the $30 million five-year DMRP results in saving approximately two cents per cubic yard dredged in five years, the savings alone would pay for the total cost of the research program during its lifetime. It is difficult to envision a situation where a concentrated effort of the type

being conducted by the DMRP could not result in much greater savings in the cost of dredging than the cost of the program.

In addition to the Corps of Engineers DMRP being conducted at WES, research is also being conducted in certain Corps of Engineers districts. There has been an attempt to coordinate these multiple research efforts. Generally, the DMRP focuses on development of a set of guidelines that can be utilized by the Corps district to evaluate the environmental aspects of dredging and dredged material disposal. Research sponsored by the Corps districts usually focuses on specific problems within the district. For example, one of the more intensive studies is being conducted by the San Francisco District. This district has initiated a several million dollar, multi-year study on some aspects of the environmental impact of dredging and dredged material disposal in San Francisco Bay. Particular attention has been given to situations which are peculiar to the Bay.

The US EPA has also sponsored some research on dredging and dredged material disposal. These efforts must be considered relatively modest compared to the Corps of Engineers activities in this area.

Current Dredged Material Disposal Criteria

At this time there appears to be an overlap between PL 92-532 and PL 92-500 of jurisdiction for the criteria covering dredged material disposal in the coastal waters of the US. Further, the situation in marine waters is complicated by the "Ocean Dumping Treaty" that was signed by the US. The amendments to PL 92-532 have brought these regulations in line with the "Ocean Dumping Treaty". It is the policy of the US EPA at this time that PL 92-532 is to be used to govern dredged material disposal in marine waters while PL 92-500 is to govern dredged material disposal and fill material in fresh waters, with PL 92-500, Section 404 covering the deposition of fill material in marine waters. In the Great Lakes region the regulations are further complicated by the Canada-US

Water Quality Agreement of 1972 which comes under the auspices of the International Joint Commission.

Probably the most important current pending guidelines governing dredging and dredged material disposal are set forth in the September 5, 1975, "Federal Register". These guidelines are designed to meet the requirements set forth in PL 92-500, Section 404. While there is some difference between the approach given in these guidelines which are currently "interim final" guidelines from PL 92-532, basic differences are minor. Ultimately, it is likely that PL 92-532, the Canada-US Water Quality Agreement and the "Ocean Dumping Treaty" will all base their procedures for determining whether a particular sediment dredged from a US waterway may be deposited at a particular location on the approach outlined in the September 5, 1975, "Federal Register".

Until the September 5 "Federal Register", all previous guidelines were based on an arbitrary approach to determining the suitability of a particular dredged sediment for open water disposal. Examination of the September 5 "Federal Register" shows that for the first time all the arbitrary approaches used to determine the significance of chemical contaminants in dredged sediments used in the past have been eliminated. Each particular dredging and disposal situation must now be reviewed on a case-by-case basis. The Corps of Engineers District Engineer now has to evaluate the potential environmental impact of a particular dredging operation on a case-by-case basis. If he finds it is in the best interest of the public to proceed with certain dredging and disposal operations, he may issue a permit for those particular operations. The US EPA and the states in which the dredging would take place may disapprove of this permit if they do not agree with his assessment.

Particularly noteworthy in the September 5 "Federal Register" is the complete absence of a 1.5 factor. This factor was specified in the original version of the test to determine whether contaminants associated with a particular sediment released in the Elutriate Test may be adverse to water quality at the disposal site. Also eliminated is the mandatory use of bulk chemical criteria.

The case-by-case approach outlined in the September 5 "Federal Register" requires that the District Engineer take certain actions prior to issuance of a permit for dredged material disposal. He must examine the character of the dredged materials and may, in those instances where he feels it important, utilize the Elutriate Test as one of the bases for determining significance of chemical contaminants in dredged sediments. Further, he must consider using, and where appropriate, adopt, a bioassay procedure and other tests to determine the significance of chemical contaminants to aquatic organisms at the disposal site.

The September 5 "Federal Register" also specifically considers the destruction of wetlands, impairment of water quality in the disposal site water column, effects of smothering of benthic communities and changes in the morphology of the area as a result of dredging or deposition of dredged and fill material. There is particular concern related to morphology changes which could affect the physical, chemical and biological characteristics of a particular area by influencing water circulation patterns.

The District Engineer must also consider as part of permit application review, the volume and rate of discharge of dredged and fill material, type of discharge and the hydrodynamic regime at the disposal site. The September 5 "Federal Register" specifically requires that he apply any applicable water quality criteria to the perimeter of the disposal site to judge significance of Elutriate Test results. For each disposal operation, a certain size mixing zone must be defined and appropriate water quality criteria applied at the boundary of this mixing zone to determine whether release of contaminants associated with disposed material is significantly adverse to aquatic communities outside the disposal area.

As discussed by Lee *et al.* (6), the September 5 "Federal Register" is still deficient regarding the oxygen status during Elutriate Tests in the manner in which the test vessels are mixed. Also, this test should be used only for hydraulically dredged sediments with water-sediment ratios of about 1 part sediment to 4

parts water. Any dredging technique that deviates significantly from this, such as the mechanical dredging frequently practiced in New England, should not be governed by the 1 to 4 ratio that has been prescribed in the September 5 "Federal Register". Further, as discussed below, for most dredge and fill operations, there is little or no information on the critical concentrations of chemical contaminants associated with a short-term high concentration exposure that might occur in a typical dredged material disposal operation. Finally, the Elutriate Test as currently described should not be used for determining the significance of chemical contaminants associated with fill materials.

The September 5 "Federal Register" also requires that prior to issuance of a permit, the District Engineer must establish a mixing zone. This should be as small as possible and take into consideration any stratification that occurs in the water column at the disposal site, current velocities, direction and constancy at this site and the surface area, shape and volume of water at the disposal site that would be affected. It specifically mentions the use of mathematical models and on-site studies to define the size of the mixing zone.

The September 5 "Federal Register" specifically delineates that dredged material disposal in water should avoid discharges that

1) significantly disrupt the chemical, physical, and biological integrity of the aquatic ecosystem,
2) significantly disrupt food chain, decrease diversity of animals and plants,
3) inhibit movement of fauna,
4) destroy wetlands,
5) alter flooding tendency of area,
6) degrade water quality,
7) significantly increase turbidity,
8) degrade aesthetic, recreational and economic values,

9) increase eutrophication i.e., significant (N & P) nutrient release,
10) release pathogenic organisms, and
11) release oil and grease.

It further delineates that there shall be no discharges in or near

1) municipal water supply intakes,
2) important shellfish areas,
3) fish spawning and nursery grounds,
4) endangered species habitat, and
5) submerged vegetation.

Anyone familiar with almost any of the above listed requirements knows that the information needed for determination of these factors with a high degree of reliability is lacking.

Dredged Material Research Needs and Deficiencies in Current Research

It is evident that what is needed to properly implement the September 5, 1975 "Federal Register" is a substantial research program to provide the information needed by the District Engineer to evaluate properly the various parameters outlined above. The current research being conducted as part of the DMRP and in the certain Corps Districts as well as that of the US EPA and other agencies will make a substantial contribution to providing this kind of information. However, especially with respect to the DMRP, there are a number of areas that are delineated in the September 5 "Federal Register" which will not be covered in this research program. The DMRP was intended to be a broad scale research program covering various aspects of dredging and dredged material disposal. As noted above, in addition to considering aquatic disposal, the DMRP also considers habitat development, disposal operation, and research on productive uses.

A substantial amount of the DMRP funding is devoted to habitat development research. While this is an important area of the overall picture of dredged material disposal, it is not one of the

primary reasons why the DMRP was initiated. Dredged material research in the US must have as its primary focus evaluating the significance of chemical contaminants associated with dredged sediments. It is this area that caused the DMRP to come into existence, and it caused dredged material disposal costs in various parts of the country to increase by 10 to 20 percent during the past several years. At this time insufficient attention is being given to properly evaluating the environmental impact of the chemical contaminants associated with dredged sediments. About 30 to 40 percent of the total DMRP budget has been devoted to aquatic disposal research. The remainder is devoted to other areas.

The DMRP and the various Corps Districts' research programs, as well as that of the US EPA, have expended considerable amounts of funds on these topics. Yet, information available now or that will be available at the end of the DMRP in 1978 will be insufficient to properly delineate (without a further research effort) for most dredging sites whether there are likely to be any significant problems associated with DDT, mercury, zinc, or other contaminants at the dredged material disposal site. At the end of the DMRP, about two years from now, the District Engineers will still not be able to determine with any high degree of reliability whether disposal of a certain sediment with certain chemical characteristics will

1) significantly disrupt the chemical, physical and biological integrity of the aquatic ecosystem,
2) significantly disrupt the food chain or decrease diversity of animals and plants,
3) degrade water quality,
4) increase eutrophication, or
5) release significant amounts of oil and grease.

A significant increase in total funding for research in this area is urgently needed. It is likely that it, like the overall DMRP, will be highly cost effective in that money spent for research will more than repay itself in terms of developing a rational, more economical and ecologically sound approach toward dredging and dredged material disposal in the US.

Laboratory vs Field Studies

Particular emphasis must be given to field studies designed to evaluate at a variety of locations throughout the US, the actual environmental impact of a particular dredged material disposal operation. Far too much of the money that had been available for both the Corps and the US EPA has been devoted to what might be termed mechanistic type research projects rather than to investigations of what actually happens during a dredged material disposal operation. The apparent basic philosophy of those initiating this type of research was that rather than study each and every situation, it would be far better to understand the mechanisms of release of contaminants from dredged sediments and then, based on this understanding, predict what might happen at another site.

Unfortunately, the aqueous environmental chemistry of trace contaminants associated with natural water sediments is such that the likelihood of understanding the mechanism of release of a wide variety of contaminants to the water or aquatic organisms at the disposal site is nil in the foreseeable future. The more or less classical approach of a laboratory study where variables are controlled and varied one or two at a time has proven to be of limited value. Far too much of the dredged material research dollar has been devoted to laboratory studies rather than field studies. What is needed is a series of field studies in which the physical, chemical, and biological characteristics of the sediments and disposal site are determined with enough reliability to detect whether there has been a sufficient change in the numbers and types of disposal site organisms to justify alternate methods of dredged material disposal.

One of the primary problems with laboratory studies for dredged material research is that at this time we do not have an adequate understanding of the field situation to properly simulate it in the laboratory. Rather than employing laboratory studies as a first phase of research, detailed field studies should have been initiated. These could be followed by laboratory studies once understanding of

the actual operating systems is sufficient to properly design laboratory investigations.

Another significant major problem with laboratory studies on dredged sediments is that frequently the sediments have been substantially altered from their natural state by sampling and subsequent handling. Results of these studies would have little or no applicability to the real world. It is important that any studies that are done on the significance of chemical contaminants associated with dredged sediments be conducted in such a way as to preserve these contaminants and sediments in their original form.

An example of this type of problem of laboratory versus field studies would be an attempt to use hydroponic techniques to try to assess heavy metal uptake from dredged sediments by marsh grasses. One cannot translate in a meaningful way heavy metal uptake of heavy metals from dredged sediments. The primary difficulty relates to the fact that the forms of the heavy metals in sediments are markedly different from those in hydroponic solution. It is well known that uptake by plants is dependent on specific forms and not total content of the sediment or solution.

Rather than using the hydroponic approach to try to assess availability of heavy metals to dredged sediments one should go to the field and measure the characteristics of sediments and heavy metal content of the marsh grasses growing in the sediments from a wide variety of locations throughout the US. If it is shown that certain types of grasses tend to accumulate heavy metals from contaminated waterway sediments, then studies should be initiated to define the significance of uptake on the aquatic ecosystem. It is probable that in many situations any contaminant uptake by wetland or terrestrial plants is of little or no consequence to the aquatic ecosystem since the rate of uptake and the ultimate availability to other parts of the aquatic system is such that no significant problems are associated with the transfer from the sediments to the plants and eventually to the aquatic ecosystem.

Focus of Field Studies

Any field studies must include detailed studies of the actual dredging operations. Information is urgently needed on the water-sediment ratio used in hydraulic dredging, various types of dredging operations and the degree of mixing of hydraulically and mechanically dredged sediments in the disposal site water column. The Elutriate Test currently specified in the September 5 "Federal Register" is designed for hydraulically dredged sediments. However, a substantial quantity of sediment is mechanically dredged (especially in New England). Hydraulically dredged sediments are typically slurried in a one-to-four or one-to-five sediment-water ratio. The amount of water associated with mechanically dredged sediments is normally much smaller. The result is a much more compact sediment, in some instances a cohesive mass that settles to the bottom rapidly and with very little interaction between it and the disposal site water column.

Field studies must assess the rate of mixing of contaminants from the dredged material disposal operation with the water column at the disposal site or, if in a diked area, with nearby waters that receive the overflow. The September 5 "Federal Register" specifies that the District Engineer shall determine the mixing zone associated with a particular disposal operation. The perimeter of this mixing zone is to be used as a basis for judging the significance of chemical contaminant release at the disposal site. The Corps of Engineers DMRP is doing some work in this area, which, however, needs to be greatly expanded. Greater attention should be given to field studies which can be used to develop generalized mathematical models that could be applied to any area once the overall dominant characteristics such as water depth, current, type of dredging and disposal operations are defined.

Chemicals that should receive attention in any research program include the heavy metals, organics with particular emphasis on persistent organics such as chlorinated hydrocarbon pesticides and PCB's and aquatic plant nutrients such as nitrogen and phosphorus compounds.

Current Constraints in Field Studies

The DMRP as well as some of the various Corps district studies have included detailed field studies. However, many of these studies have been conducted under very significant constraints which were in part related to the way in which the Corps can fund research. Studies of the type that are needed are extremely expensive, often requiring something in the order of a million dollars per year per site. This estimate is based to some extent on the amount of funds that has been spent by various electric utilities studying the environmental impact of using once-through cooling at electric generating stations. A number of utilities have spent between one and two million dollars per year for several years to assess the environmental impact of once-through cooling on receiving water quality. Disposal of dredged sediments in water or on land with overflow of supernatant water to the nearby water course is a similar problem and will require similar funding. Thus far the amount of funding available for research in this area has fallen considerably short of this amount. This is certainly the most significant deficiency with respect to research in this area. Instead of spending the present few million per year, from ten to fifteen million dollars per year should be spent for a five-year period at selected locations in the US in order to evaluate properly the actual environmental impact of disposal of dredged sediments.

Some of the other important problems with respect to conducting studies of this type are funding constraints that are placed on governmental agencies. These include limits on the total funding that can be readily allocated to one investigator during a specified contract period and normal award periods of one year.

In addition, often politicians and/or social groups in a particular area will impede and in some instances completely suspend a particular study. A few years ago it was common for legislators to exert influence on funding agencies to conduct water quality studies within their area. There have been several instances, particularly in New England where the Corps of Engineers has had to

terminate a dredging research project because the local citizenry and congressional leaders opposed the study. A prime example of this is Bradford, Connecticut, where the residents told the Corps that while they fully appreciated the value of marshlands, they did not want any additional marsh built in their area.

Another very significant problem is that there is an insufficient number of competent researchers available to fully utilize what funds have been made available under the current constraints. The RFP system of awarding research contracts has, in numerous instances, resulted in the awarding of substantial funds to contract study groups which were unable to conduct the study in a meaningful way. This is largely a result of the fact that the peer system review that was once in effect in the water pollution field has been largely terminated in the US EPA and does not exist within the Corps of Engineers.

Another significant problem with dredging and dredging research is the fact that while Corps districts, the DMRP and the US EPA will sometimes appoint non-agency advisors to review an overall program, in some instances these advisors have limited influence on determining the priority of funding and the overall approach that is used within the particular program. In several instances dredged material research programs have been developed with limited input by non-governmental agency personnel. After the program has been initiated, non-agency personnel are brought in to review the program and point out its deficiencies. However, only rarely can major changes be made in funding allocations because the program is usually committed to a certain approach for several years. Therefore, the advisory group can have little impact on the overall course of the study and the overall allocation of funds among the various study components.

Of course, the research program should not be changed with such frequency as to disrupt the continuity in achieving the overall objective of the program.

The September 5 "Federal Register" specified that the agencies responsible for determining the regulations develop procedures for

evaluating the environmental impact of dredged material disposal and delineated a number of specific factors, such as those listed previously, that must be considered by the District Engineer. Those responsible for conducting research in this area should certainly carefully review whether the previous allocation of funds will meet the needs of the District Engineer in implementation of the September 5 guidelines.

The September 5 "Federal Register" did promote a small amount of funding for aquatic disposal research within the Corps of Engineers. The additional increment, however, is in the opinion of the author inadequate to even begin to develop a research program of the magnitude needed to fully implement within a short time the provisions of the September 5 "Federal Register" as they relate to determining the environmental impact of dredged material disposal.

The various constraints discussed above lead to situations where high intensity-short term programs such as the current efforts in dredged material research in the US often have a relatively low efficacy. It is the author's opinion, however, that based on his experiences in being involved in a number of high intensity-short term studies of this type in the environmental quality area, that the current Corps of Engineers Dredged Material Research Program efficacy is at least equal and in general better than most of the previous, or for that matter, current efforts to provide information on a specific aspect of environmental quality that could be used to determine public policy in a specific area.

Research Needs for Chemical Aspects of Dredged Material Disposal

It is important to break down potential environmental impact of chemicals associated with dredged sediments into a short-term, high-intensity effect related to the release of contaminants to the water column at the disposal site or in the overflow waters from a diked disposal area and long-term chronic exposure which could occur to benthic or epibenthic organisms that inhabit or attempt to inhabit the dredged material disposal site once the sediments

have been redeposited on the bottom. These two areas have distinctly different characteristics and must be treated differently.

Characteristics of Disposal Sites

Field studies on the significance of chemical contaminants in dredged sediments must focus on at least two, and in some cases, three distinct areas. In coastal zones the focus must include the potential environmental impact of disposal in nearby open waters and in diked disposal areas in the water and on land. In some parts of the country deep ocean disposal must also be considered. The latter is frequently being used today for disposal of highly contaminated sediments. In some areas, regional agencies adopted the policy that disposal of contaminants associated with dredged sediments has less environmental impact in deep waters than in shallow waters. This is a supposition that has not been borne out by any experimental results. A number of aquatic scientists question whether barging to deep water is an ecologically safe method of dredged material disposal. This is an area that is not receiving sufficient attention at this time and should be studied in order to evaluate the actual environmental impact of deep water disposal of dredged sediments on aquatic ecosystems.

The primary emphasis in dredged material research has been on evaluating the significance of chemical contaminants associated with dredged sediments disposed of in waters near the dredging site. As noted above, this was the most frequent method of dredged material disposal prior to adoption of bulk chemical "Jensen criteria" by the US EPA and its predecessor organizations. In accordance with these criteria, almost all polluted and non-polluted sediments were disposed of in nearby water courses or on land where overflow quickly returned to the water course.

Some of the current efforts within the dredged material research programs conducted at WES and in the districts are devoted primarily to evaluating the impact of dredged material disposal in water. Many of these studies are deficient in that they are devoted

to evaluating the environmental impact of relatively clean sediments. Few of these studies actually involve evaluating the impact of what most individuals would consider grossly polluted sediments.

An exception to this was the work for the DMRP at Galveston, Texas, where the study compared the environmental impact of disposal of dredged sediments from the Galveston Entrance Channel (relatively non-contaminated) to that of sediments from the Texas City Channel, a heavily industrialized area which received petrochemical and other industrial wastes. This study focused on the short-term effect of dredged material disposal on water column characteristics. With respect to these characteristics, it was found that grossly polluted sediments had the same environmental impact as clean sediments. Neither would have a significant deleterious effect on organisms present in the water column at the disposal site.

More studies of this type should be conducted in order to see whether there are situations elsewhere in the US in which highly contaminated sediments have a significant adverse effect on water quality in the water column at the open water disposal site. Based on the characteristics of most dredged material disposal operations, this appears most unlikely.

One of the outgrowths of the Dredged Material Research Program of the Corps is the Elutriate Test. This is designed to evaluate the potential impact of chemical contaminant release from hydraulically dredged sediments on the disposal site water column. Research currently under way is investigating how well this test predicts the release of contaminants during an actual disposal operation. Further research is needed along these lines in order to see if the preliminary results are borne out for a wide variety of sediments and locations in the US.

An area that is not receiving sufficient attention in the current dredged material research programs conducted by the Corps and the US EPA is the environmental impact of overflow waters from diked disposal operations. As noted by Lee (3), this method of disposal has been adopted in numerous places throughout the US as a means of disposal of (according to the bulk criteria) more polluted

sediments. Lee and others point out that dredged material disposal in diked areas either in water or on land and with overflow of supernatant water to the nearby water course may be ecologically more damaging than open water disposal. This is because most of the significant contaminants associated with dredged sediments would be present in the overflow waters which would enter what are generally the most sensitive areas of a water body, i.e., the near shore waters where the larval immature forms may be present. These are areas with relatively lower mixing than open waters, where generally the contaminants are rapidly dispersed. There is an urgent need for additional research on the environmental impact of diked disposal overflow waters. An effort at least equal to the open water disposal research efforts should be mounted immediately in order to enable the District Engineer to properly evaluate the environmental impact of open water versus diked disposal area disposal. Such research would be particularly important in the Great Lakes region where each of the states bordering on the lakes (except Ohio) has arbitrarily adopted a policy of a complete diked disposal operation at a cost of tens of millions of dollars. Based on the available information, no one can be certain that diked disposal operations currently being implemented will have less environmental impact than the formerly used and less expensive open water disposal techniques.

Another problem with attempting to delineate the effects of dredged material disposal on aquatic ecosystems is that other man-associated activities such as passing of ships through an area and natural phenomena such as storms and high flow periods may stir up as much or more sediments from the bottom in a few hours as may take place in many years of dredged material disposal in a given area. There is need for research devoted to evaluating the environmental impact of other types of events arising from suspension of sediments in order to properly assess the significance of a particular dredged material disposal operation.

One of the areas which, in the opinion of the author, should not receive a high priority for funding includes attempts to develop

mathematical models to predict the fate and significance of chemical contaminants associated with dredged sediments. At this time and certainly in the foreseeable future, the understanding of the environmental chemistry of these contaminants is such that it is extremely unlikely that any modeling efforts along these lines would be successful.

Water Quality Criteria

One area that needs particular attention at this time is the identification of concentrations of sediment-released contaminants critical to water column organisms for short times of exposure. The September 5 "Federal Register" specifies that any applicable water quality standards should be applied to the perimeter of a mixing zone where dredged material disposal is taking place. The natural tendency would be to apply the current or soon-to-be-reviewed water quality standards that each state has for its waters to this area. However, water quality criteria based on a 96 hour acute toxicity or chronic (long-term) toxicity are not generally applicable to typical dredged material disposal operations. It is rare and sometimes impossible for aquatic organisms in the water column at or near a disposal site to be exposed to the contaminants for four days (96 hours) or for a chronic exposure period. More typically, aquatic organisms present at or near the disposal site would be exposed for a few minutes to a few hours.

Of particular concern is the potential significance of ammonia released from dredged sediments. Essentially nothing is known at this time about the toxicity of ammonia to various forms of aquatic life for one hour, two hours or one day. It is certainly inappropriate to apply most state water quality standards for ammonia to typical dredged material disposal operations. Certainly one should never apply the chronic exposure limit proposed by the US EPA (0.02 mg/l) ammonia) for dredged material disposal operations because these are usually intermittent and rarely of long duration at any one disposal site.

Significance of Chemical Contaminants in Redeposited Dredged Sediments

Direct Toxicity

The significance of chemical contaminants associated with the particulate fraction which ultimately settles to the bottom is another area that needs substantial research. Such research is quite difficult and in general requires an approach markedly different from the usual approach. The basic question is whether chemical contaminants in disposed sediments have a significant adverse effect on water quality, including benthic, epibenthic organisms and higher trophic level organisms. The question is not, as is sometimes posed, one of whether disposal of dredged sediments can have an adverse effect on benthic organisms. They certainly do. Effects associated with the physical aspects of disposal such as burying, smothering, changing particle size and organic content, etc. must be evaluated in their own right. Moreover, there are obviously certain ecologically sensitive areas where dredged material disposal should not take place. These include fish spawning areas, coral reefs, oyster and other shellfish beds because of the potential physical harm to the benthic communities. This area requires research and appropriate regulations independent of the chemical content of the sediments.

Primary concern must be over whether contaminants such as mercury, zinc, DDT, etc. present in waterway sediments can create a significant adverse effect on the benthic organisms at the disposal site. Most importantly, it is necessary to know whether this effect is of sufficient magnitude to warrant use of an alternate method of disposal where it is known that the potential environmental impact of these chemicals could be lessened or eliminated. It should be emphasized, however, that this does not mean adoption of on land disposal with overflow of these same contaminants to nearby waters. As noted above, this may be more damaging to the aquatic ecosystem than open water disposal. Instead, the choice

generally is between open water disposal with some effect on the numbers and types of benthic organisms within a specified area, and on land or diked area disposal with or without complete containment, i.e., no overflow. The latter would entail treatment of overflow waters to remove the contaminants, much the same as that used for municipal and industrial wastes. Of course, this would be expensive and would greatly increase the cost of dredged material disposal. At this time the District Engineer has limited information to begin to evaluate these options. The DMRP, the US EPA and Corps District research in these areas is also inadequate to provide the needed information.

The effects of chemicals on benthic organisms must be considered from two points of view. First, dredged material disposal could have a direct toxic effect by which certain numbers or types of organisms are killed. More importantly, however, the disposal area could remain toxic to certain forms of benthic organisms, creating a biological desert in the disposal area. This possibility requires additional research. However, at this time no one is in a position to evaluate the consequences to the overall ecosystem of removing a certain amount of the benthic fauna from the ecosystem, and especially the effects of this removal on the beneficial uses of the water to man. Certainly creation of a biological desert in which a large area is essentially devoid of higher forms of benthic or epibenthic organisms should be avoided. However, when one compares the potential significance of this type of situation to the cost of alternate methods of disposal and the benefits derived from dredging of a particular waterway, this could be desirable from a societal point of view.

A much more difficult question concerns the significance of changing the numbers and types of benthic and epibenthic organisms in a specific area of a particular ecosystem. Is a change from one type of worm to another important to the ecosystem? Such a change could be traceable to a specific chemical contaminant or to some physical characteristic of the dredged sediments. If it is important, how important is that change to man? How much of our financial

and natural resources and energy are we willing to expend in order to prevent minor changes of this type? These questions must be addressed by comprehensive field studies coupled with social-economic evaluations of the impact of the results before one can decide whether chemical contaminants present in dredged sediments are significantly disrupting the chemical, physical and biological integrity of an aquatic ecosystem as defined in the September 5 "Federal Register."

It is apparent that there is need for research to focus on developing a bioassay procedure that could be utilized to determine whether chemical contaminants present in a sediment that is scheduled for dredging could be adverse to benthic organisms at the disposal site. Basically what is needed is an Elutriate Test type procedure which could be used to screen sediments prior to dredging which would sort out potentially significant adverse effects on benthic organisms attempting to repopulate the dredged material disposal area.

Food Web and Bioaccumulation

The other area that must be considered is the potential for the transfer of chemical contaminants from dredged sediments to the benthic organisms at the disposal site and then up through the food web to higher forms of aquatic life, such as fish, fish-eating birds, and/or man. The National Academies of Science and Engineering, in their Water Quality Criteria (NAS-NAE, 1972) (7), and the US EPA in its proposed Quality Criteria for Water (1975) (8) have recommended limits on the concentrations of mercury, DDT, PCB's and other contaminants in water. These limits were based on the fact that these contaminants accumulate in the food web to excessive concentrations in higher trophic forms such as fish which are utilized by man as food. These concentrations in the higher forms may exceed the FDA limit for the particular contaminant. Therefore, the significance of the contaminant is no longer limited to the effect on aquatic organisms at the disposal

site. They may all be perfectly healthy. However, they may accumulate sufficient concentrations of the contaminants in a particular food resource to exceed the FDA limit.

Numerous individuals have pointed out that the basis of some of the FDA limits such as those for DDT and mercury in fish (which ultimately establishes the water quality criteria for these elements in natural waters) is lacking in technical foundation. However, political considerations make raising a particular FDA limit virtually impossible. Therefore, society is largely stuck with what was originally a relatively arbitrary decision on what comprises the critical concentration of some contaminants in man's food.

The role of benthic organisms in transferring contaminants from natural waters to higher trophic levels is very poorly understood at this time. It is well known that in most natural water systems the majority of the contaminants of concern are associated with sediments. However, concentration factors used by the National Academies Water Quality Criteria generally are based not on sediment concentrations but on total concentrations in the water column. At this time no one knows with any degree of reliability the relationship between contaminant concentrations in sediments and the magnification of the contaminants in the food web. It is, however, reasonable to expect that this magnification would tend to be smaller than that observed in contaminant transfer from water or finely divided materials suspended in the water column to higher trophic forms.

It is unlikely that determining mechanisms or even the extent of food web accumulation of contaminants from dredged sediments will be developed to any significant degree as a result of the current research. There is an urgent need for substantial expansion of this research in order to investigate this specific potential problem area. However, it should be noted that the likelihood of this potential problem becoming a significant problem in many parts of the country is small.

Except for DDT, PCB's and mercury in some areas of the US, there do not appear to be significant problems associated with food web accumulation of various heavy metals or other contaminants. Therefore, with the exceptions noted above, organisms are not obtaining excessive concentrations from all of the potential sources. It appears that even if dredged material disposal did increase the availability of contaminants to a certain group of organisms, these contaminants probably would not contaminate higher forms of aquatic life to the extent that these forms are not suitable for human consumption. The approach that should be taken is to determine whether benthic or epibenthic organisms which are of commercial importance to man in a particular area contain excessive concentrations of chemical contaminants which could be related to dredged material disposal. This is an area that needs considerable additional study.

It is important not to make the mistake of some of the individuals working in this area of assuming that there is something significant about the uptake of a contaminant in a benthic organism. Some investigators in this area have focused their efforts on detecting whether contaminants are taken up from dredged sediments. No funds are provided to go beyond this initial question. Leaving it at that point does a gross injustice to the District Engineer and the public. Finding that a particular contaminant is taken up by a particular type of worm is of no consequence unless one can determine that this uptake is of significance with respect to the aquatic ecosystem or food web accumulation where higher trophic forms including man are adversely affected by this uptake.

One of the major problems associated with working on the environmental impact of dredged material disposal on benthic organisms is the fact that sediments in a particular region tend to be highly variable at relatively close distances in both organism and chemical content. This requires that a very expensive well-thought-out and designed research program be initiated to determine whether the chemical contaminants present in dredged

sediments have a significant adverse effect on benthic organisms at the disposal site. The levels of funding associated with studies of this type thus far have not been adequate to begin to properly conduct the types of field investigations necessary to delineate cause and effect between chemical contaminants in sediments and long-term repopulation of a dredged material disposal area. Often tens to as many as hundreds of samples must be taken at a specific site in order to obtain reliable estimates of the populations at that site compared to some other site where dredged material disposal has not taken place. Further, sampling has to be done with fairly close frequency since the benthic organisms in a particular area are often subject to considerable change due to natural causes such as storms, normal growth and reproduction, grazing by higher forms and seasonal changes.

All of these factors tend to greatly escalate the cost of assessing the subtle environmental impact of contaminants on benthic populations. This is specifically true if one has as the objective of the study to clearly define with a known degree of reliability whether the chemical contaminants present in a particular dredged sediment are having an adverse effect on the aquatic ecosystem. Most investigators in the water pollution field have been faced with sufficient limitation on the funds available for support of their benthic organism water quality studies so that they had to take a qualitative or semi-qualitative approach where at the end of the study the best that could be done was to say that there is a possibility of effect if the data obtained thus far is truly representative of the system.

One of the greatest difficulties associated with determining the factors controlling the numbers and types of benthic or epibenthic organisms is the fact that the physical characteristics of the sediments as well as some bulk chemical characteristics often appear to play dominant roles. The likelihood of sorting out the effect of trace chemical contaminant effects when bulk characteristics of the sediments are also changed as a result of disposal of dredged material is extremely remote.

The situation is further complicated by the fact that if one does find that chemical contaminants present in the sediments do have a significant adverse effect on numbers and types of organisms present, they still must wrestle with the significance of this effect to the ecosystem as a whole and determine the significance of this effect to man's use of a particular water body.

Research on Wetlands and Fill Material

There are two areas in the September 5 "Federal Register" that deserve particular attention. These are not specifically related to dredging and dredged material disposal except under special circumstances. One of these is that of the District Engineer's responsibility for the protection of wetlands of the country. The September 5 "Federal Register" has included within it a provision that it is the responsibility of the District Engineer to preserve and protect the wetlands of the country. In accord with these regulations, anyone who wishes to conduct any operation in an area of wetlands must obtain a permit from the District Engineer. The justification for including this new responsibility within the September 5 "Federal Register" relates to the fact that often one of the primary areas of disposal of dredged sediments is wetlands. However, the September 5 "Federal Register" goes considerably beyond consideration of the environmental impact of deposition of dredged sediments in wetlands and includes consideration of all activities which could have an effect on wetlands. The significance of this regulation is primarily related to its potential impact on growth and development of urban areas near wetlands.

One of the areas that needs additional attention is the impact on the aquatic ecosystem of dredging or filling a certain amount of wetlands. There are basically two approaches that could be taken with respect to preservation of wetlands. One is the ultra-conservative approach of stopping all activities of man which alter or

reduce the total amount of wetlands available within the US and the other is to try to assess the impact of a particular activity in removing a certain amount of wetland and its associated environmental impact compared to the social benefits from utilization of wetlands for other purposes. The September 5 "Federal Register" pushes hard toward complete preservation but does allow the District Engineer the option of placing dredged and fill material in wetlands where it is thought to be socially desirable. In order to make this judgment, the District Engineer needs additional information on the potential value of wetlands to aquatic ecosystems.

A considerable amount of the DMRP funds are devoted to habitat development and marsh creation. This work could have some importance in helping the District Engineer in assessing the significance of marshes and wetlands to aquatic ecosystems. However, the work in this area is not adequate to provide the District Engineer with the information needed to define the significance of wetlands. A significant increase in the total amount of funds for this area must be made in the immediate future.

The second area which is included in the September 5 "Federal Register" but is not necessarily related to dredged material disposal is that of placement of fill material in the nation's waters. Anyone who wishes to place fill material in any waters of the US which are classified as navigable, i.e. for lakes or impoundments having a surface area of 5 acres or greater or for streams having a flow of 5 cfs or greater, must obtain a permit from the District Engineer. As written now, the placement of fill material in water is subject to the same kind of evaluation and testing as that of dredged sediments. While there is no doubt that there is need for evaluation of the pollutional tendencies of fill material, this material should not be treated the same as dredged sediments and certainly the Elutriate Test which is designed to help predict the environmental impact of disposal of hydraulically dredged sediments in water should not be used to evaluate the potential impact of contaminants associated with fill material unless, of course, the fill

material is being added as a slurry with a 1 to 4 sediment to water ratio. There is a need to consider the approach that should be used to evaluate the significance of contaminants associated with fill material. These efforts should be conducted separately from those of evaluating the environmental impact of dredged material disposal because of the different character of the material and the markedly different ways in which fill material may be generated and placed in water.

A closely related problem to that of including within one regulation, guidelines for disposal of dredged sediments versus that of placement of fill material is the frequently encountered problem of the public and legislators treating disposal of sewage sludge in water the same as disposal of dredged sediments. Based on the information available, one should not equate these two types of materials as having similar environmental impacts. With few exceptions, dredged sediments are largely inorganic materials consisteng of sand, silt, and clays with normally a relatively small percentage of organic materials. The situation prevails even in sediments dredged from grossly polluted harbors. However, sewage sludge is primarily organic in nature, and often contains high concentrations of contaminants and human pathogens removed during the domestic or industrial wastewater treatment processes, many of which would be in a form that could become mobile upon placement in water. One way to greatly reduce the mobility of these contaminants and prevent them from entering the overlying waters at the sewage sludge disposal site is to mix the sewage sludge with inorganic materials such as those normally present in dredged sediments. Such a process would tend to detoxify the contaminants by putting them into a form which in unavailable or sparingly available to aquatic life and to the overlying water column.

Treatment and Beneficial Uses of Contaminated Sediments

It is likely that some sediments in US waterways contain chemical contaminants which could have a significant adverse effect

on water quality at a particular open water or on land disposal site with overflow to the nearby water course. Therefore, it is important that work be conducted on methods of treating these contaminants from on land disposal in order to prevent contamination of surface or groundwaters. This is an area that is receiving some attention in the current Dredged Material Research Program. However, it is an area that needs greatly increased research with particular emphasis on its engineering and economic aspects.

Based on current information, beneficial uses or reclamation of areas that have been used for dredged material disposal in the past should receive a lower priority for research dollars associated with dredged material disposal. It is doubtful that in the foreseeable future the public will spend any substantial amount of money for habitat development associated with dredged material disposal. While some beneficial uses, such as reclamation of mined land, can be made from dredged sediments, generally this does not appear to be an area of great promise. It should receive a relatively low funding priority compared to the other more pressing problem areas that exist, such as those enumerated above.

Implementation of September 5 "Federal Register"

It is reasonable to question whether the current gaps in the knowledge prevent the District Engineer from making a reasonable assessment of the potential environmental impact of dredged material disposal on receiving water quality. Even though there are large gaps in the information available today which would make it difficult for the District Engineer to answer all questions that have to be considered in the September 5 "Federal Register", available information today is sufficient to take a case-by-case approach as specified in these regulations to evaluate the environmental impact of dredged material disposal. As additional information becomes available, it will be possible to refine the ability to predict the environmental impact of dredged material disposal for a given situation.

A key part of this refinement process should be a series of studies at the Corps District level designed to monitor what actually happens at the dredged material disposal site during disposal operations. What is needed is a research type monitoring program which goes considerably beyond the normal water quality surveillance monitoring that is typically done in the US. These research type monitoring programs should be set up in such a way as to provide the basic background information on the physical, chemical and biological characteristics of the area prior to disposal to enable a reasonable assessment of the changes in the aquatic ecosystem as a result of disposal.

Current monitoring programs being used by the Corps District in general are inadequate for this purpose and must be expanded. The cost of such monitoring programs should be part of the cost of dredging and dredged material disposal. Ultimately, monitoring programs can be cut back to a surveillance type program once it has been established for a particular area that the results of the monitoring program coupled with results of other research studies that are advocated in this paper are available.

As pointed out above, it is appropriate to take the conservative approach with respect to dredged material disposal in those situations where there are legitimate questions about the potential environmental impact of a certain type of contaminant in dredged sediments associated with a certain type of disposal. However, it is imperative that if one utilizes an alternate method of disposal, this disposal method is in fact shown to be less ecologically damaging than previously used methods and not, as has been widely adopted in the past, simply a transfer of the problem from one location to another, sometimes with the potential of greatly intensifying it.

Conclusions and Recommendations

The current dredged material disposal regulations promulgated in the September 5 "Federal Register" require a case-by-case

approach to evaluate the potential environmental impact of dredged material disposal on receiving water quality. This approach is technically sound but places a considerable burden on the District Engineer who must evaluate a number of specific points delineated in the regulations. Ongoing research in this area will make significant strides toward helping the District Engineer make this evaluation. However, even with the completion of the DMRP there still will be numerous questions which have not been properly addressed.

It is strongly recommended that, in light of the September 5 "Federal Register", a significant increase in funding available for dredged material research be allocated and that these funds be used specifically to evaluate the environmental impact of chemical contaminants associated with dredged sediments. There is every reason to believe that such expenditure will more than pay for itself by reducing costs of dredging and dredged material disposal and by providing guidance to development of the best overall methods of disposal considering the environmental impact and technical, legal and social factors.

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Additional reference to the topic area is found in the above cited literature. Also please contact the Dredged Material Research Program at Corps of Engineers, Vicksburg, Mississippi for the information on the results of the studies being conducted by this group.

STATEMENT OF BACKGROUND AND QUALIFICATIONS

G. Fred Lee currently holds the position as Director of the Center for Environmental Studies at the University of Texas at Dallas. He has conducted research on the significance of contaminants associated with natural water sediments. During the past five years he has served as an advisor to the US EPA and the US Army Corps of Engineers in the development of dredged material disposal criteria. At the present time he is one of the consultants to the Corps of Engineers Dredged Material Research Program and also is an advisor to the International Joint Commission Research Advisory Board and the US EPA Grosse Ile Laboratory for dredging research on the Great Lakes.