MISCELLANEOUS PAPER D-73-9

AN OVERVIEW OF THE TECHNICAL ASPECTS OF THE CORPS OF ENGINEERS NATIONAL DREDGED MATERIAL RESEARCH PROGRAM

by

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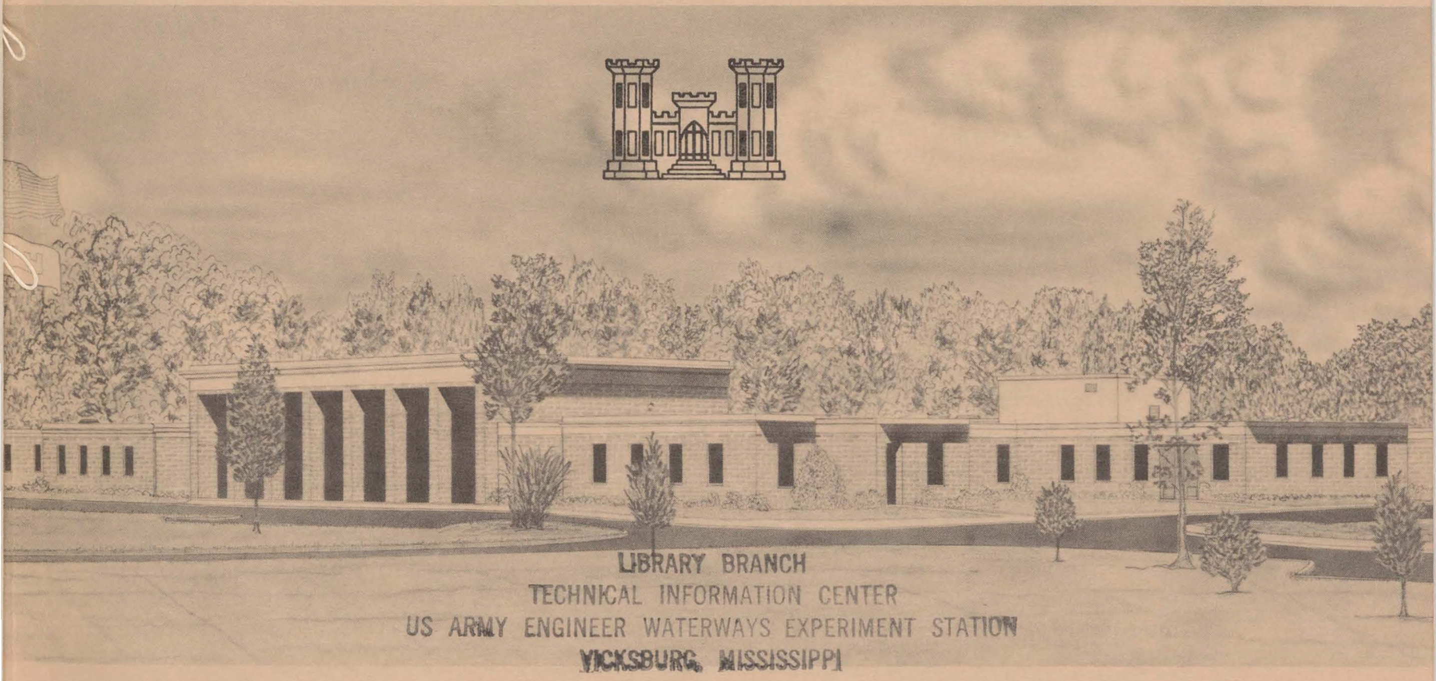

December 1973

Sponsored by Office, Chief of Engineers, U. S. Army

Conducted by U. S. Army Engineer Waterways Experiment Station
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FOREWORD

Section 123(i) of Public Law 91-611 authorized the Chief of Engineers to conduct a comprehensive research program related to dredging and the disposal of dredged material. The Dredged Material Research Program (DMRP) is sponsored by the Office, Chief of Engineers (DAEN-CWO-M), and was formally authorized by letter, "Study Program for Disposal of Dredge Spoil," dated 27 December 1971.

Phases I and II of the four-phase study identified the various problems associated with the dredging and disposal process, and developed a comprehensive plan of research to address these problems. The research effort (Phase III) was approved by the Office of Management and Budget in February 1973 and is currently under implementation by the Office of Dredged Material Research (ODMR) of the U. S. Army Engineer Waterways Experiment Station (WES). The ODMR has the responsibility of program planning, management, and research supervision of a comprehensive study designed to assess the significance and magnitude of the environmental impact of dredging and disposal operations. Additionally, viable enhancement alternatives will be developed, tested, and implemented.

This paper was prepared for the Second International Estuarine Research Conference in Myrtle Beach, South Carolina, October 1973, by Drs. Conrad J. Kirby, Project Manager, ODMR, John W. Keeley, Project Manager, ODMR, and John Harrison, Chief, ODMR; it was presented at the conference by Dr. Kirby. It summarizes the results of the first two phases of the DMRP and describes in detail the planned technical research (Phase III). The purpose of publishing this paper in this format is to provide an introductory summary of the DMRP to interested parties.

Members of the ODMR, WES, who made important contributions to this paper were Dr. R. T. Saucier, Assistant Chief; Mr. M. B. Boyd, Technical Consultant; MAJ F. H. Griffis, Jr., Program Manager; and Mr. R. L. Montgomery, Project Manager.

Directors of WES during the preparation and publication of the paper were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

SUMMARY

The realization that the dredging and disposal processes are highly complex situations and the urgency of providing definitive information on the environmental impact of current and potential disposal methods, as well as the development of techniques for mitigating potential adverse effects, have led to the development of a comprehensive five-year research program.

Due to the fact that dredging and the disposal of dredged materials occur in such highly variable environmental situations, it has been generally accepted that a universally applicable methodology cannot be satisfactorily developed. Consequently, it was concluded that a broad-based program of research was required to provide definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource.

This research effort will provide solutions to many problems within two years and to some of the more difficult and complex ones within five years. The research plan is by necessity a dynamic one and is under continuous adjustment as more information is developed from early research under this study or from other sources.

INTRODUCTION

The importance of the navigable waterways of the United States and the vital role which they have played in the nation's economic growth are reflected in the continuing major advance in total waterborne commerce which, in the 20-year period from 1950 to 1970, has increased by some 85 percent and now exceeds 1.4 billion metric tons per year. In fulfilling its mission in the development and maintenance of these waterways, the Corps of Engineers (CE) is responsible for dredging annual quantities currently averaging about 230,000,000 cu m in maintenance dredging operations and approximately 61,000,000 cu m in new work dredging. The total annual cost presently exceeds $150,000,000. The process of dredging entails removing sediments from the bottoms of streams, lakes, and coastal waters, transporting the material via ship, barge, or pipeline, and discharging it into water or onto land surfaces. Dredging is usually accomplished to maintain, improve, or extend navigable waterways or to provide construction materials such as sand, gravel, or shell. In recent years, as sediments in waterways and harbors have become polluted, a wide variety of questions has arisen over the nature and significance of the environmental impact resulting from dredging and disposal operations.

Much of the concern over the actual dredging process is related to the possibility of direct destruction of benthic communities which are known to play an important role in the aquatic ecosystem and/or include commercially valuable species such as oysters and clams. Although the direct effects of dredging on benthic organisms may appear to be obvious, there is little information available that permits the prediction or assessment of the overall extent, significance, and duration of the effects. In addition to the concern with regard to the direct effects of dredging operations, there is also concern over the possible indirect effects on aquatic communities. The potential for indirect effects is usually attributed to physical alterations of the environment such as changes in bottom geometry and bottom substrate which trigger subsequent alterations in current patterns, salinity gradients, and the exchange of nutrients between bottom sediments and the overlying water. Each of these physical changes can, either singly or in combination, initiate varying responses within the biological communities. As an example, a change in the salt water gradient may be beneficial for young fish and crab transport, yet due to the greater penetration of predators be detrimental to oysters. Within the current state of knowledge it is not always possible to definitely assess such effects or to judge whether they are of an adverse, neutral, or beneficial nature.

Most of the concern over the dredging-disposal process is directed toward the effects of open water disposal on water quality and aquatic organisms. It has long been known that, depending on individual circumstances, bottom sediments are continuously being resuspended by natural processes. Thus, under cursory examination, the open water disposal of bottom sediments may be viewed as an extension of natural processes. However, in contrast to the natural phenomenon of sediment resuspension, open water disposal often results in the resuspension of large volumes of sediments over a relatively short period of time in a relatively small area. Further, the dredging and redeposition of certain types of polluted sediment may convert a localized problem in a noncritical location to a serious regional problem as pollutants are dispersed by currents and/or carried to critically important areas such as oyster grounds and coral reefs. The effects of open water disposal are therefore often similar to those resulting from normal resuspension, but the intensity and range of the effects may be increased.

Another possible effect of open water disposal is sediment buildup, which could result in the smothering of benthic organisms, changes in spawning areas, reduced habitat diversity, and reduced or changed vegetative cover. Additionally, increased levels of suspended solids reduce light penetration, which in turn alters biological productivity, decreases the availability of food, and alters the chemistry and temperature of the water. Finally, because some of the sediments of the nation's waters have become contaminated, there is concern that man-induced resuspension of such sediments may increase the possibility of these contaminants adversely influencing biological communities. Because of the poor understanding of the possible consequences of these changes, definitive research is needed to assess all aspects of the open water disposal of dredged sediments.

Primarily because of the concern over the open water disposal of polluted sediments, a trend toward land disposal has developed. Yet without definitive research it is not possible to determine, from an overall environmental viewpoint, in which cases land disposal is in fact a wise alternative to open water disposal. Land disposal often involves marshlands or other wetlands, which are among the most biologically productive areas on earth. The effects of disposal on the role of marshlands as breeding areas, nurseries, and zones of high biological production are only marginally understood. In addition to the rather special case of marsh disposal, there are other environmental concerns that must be considered common to all types of land disposal. One of the more intensive concerns involves the possible pollution of ground water and the subsequent effects on man. Land disposal could alter vegetation assemblages and local relief, thereby triggering changes in drainage patterns and wildlife migration. The relocation of sediments from one biotype to another could be an alien intrusion of significant ecological concern. Finally, as is always the case, each of these alterations could initiate further sequences of events in both the terrestrial and aquatic regimes.

A consideration of the dredging-disposal process in even such broad philosophical terms readily points out a need for a more comprehensive understanding of the precise nature of the problems and a need to fill numerous gaps in knowledge regarding the significance of known or suspected environmental effects of dredging and disposal.

The CE was authorized by Section 123(i) of the Rivers and Harbors Act of 1970 (Public Law 91-611) to initiate a comprehensive program of research, study, and experimentation related to dredged material. The problem identification and the research effort developed and currently being implemented by the Office of Dredged Material Research (ODMR) of the Waterways Experiment Station (WES) are dedicated to these goals.[1] An outline of the Dredged Material Research Program (DMRP) is presented in Table 1 and a detailed discussion of the research areas follows in the text.

NATURE OF PROBLEM AND RECOMMENDED RESEARCH

Environmental Impact of Aquatic Disposal

In this age of "environmental awareness" as evidenced by the public's concern over the wise utilization of the nation's resources, it is of little wonder that many questions have arisen concerning the dredging and aquatic disposal of some 191,000,000 cu m of bottom sediment per year. Indeed, the sheer volume appears sufficient to warrant research investigations designed to determine the environmental impact of open water dredging and disposal operations. Unfortunately, many of the bottom sediments throughout the United States reflect the cultural pollution of the nation's waters to the extent that, by dredging, the CE is involved in waste management, treatment, and disposal. However, the concerns voiced to date go far beyond the consideration of just the quantities or pollution aspects involved in open water dredging and disposal. Many of the concerns are now directed toward the effects dredging operations may have, either directly or indirectly, on the structure and function of biological communities. Both dredging and disposal factors are involved in these concerns; as might be suspected, disposal operations are responsible for the greatest amount of concern.

Table 1

Outline of Dredged Material Research Program

Research Area	Research Task
1. Environmental Impact of Open Water Disposal	A. Evaluation of Disposal Sites (1)* B. Fate of Dredged Materials (1) C. Effects of Dredging and Disposal on Water Quality (1) D. Effects of Dredging and Disposal on Aquatic Organisms (1) E. Pollution Evaluation
2. Environmental Impact of Land Disposal	A. Environmental Impact Studies (1) B. Marsh Disposal Research (1) C. Containment Area Operation Research (1)
3. New Disposal Concepts	A. Open Water Disposal Research (2) B. Inland Disposal Research (3) C. Coastal Erosion Control Studies (3)
4. Productive Uses of Dredged Material	A. Artificial Habitat Creation Research (1) B. Habitat Enhancement Research (2) C. Land Improvement Research (3) D. Products Research (2)
5. Multiple Utilization Concepts	A. Dredged Material Drainage/Quality Improvement Research (2) B. Wildlife Habitat Program Studies (1) C. Disposal Area Reuse Research (1) D. Disposal Area Subsequent Use Research (2) E. Disposal Area Enhancement (2)
6. Treatment Techniques and Equipment	A. Dredged Material Dewatering and Related Research (2) B. Pollutant Constituent Removal Research (1) C. Turbidity Control Research (1)
7. Dredging/Disposal Equipment and Techniques	A. Dredge Plant Related Studies (3) B. Accessory Equipment Research (2) C. Dredged Material Transport Concept Research (4)

* Numbers in parentheses indicate the beginning year of the research task.

Open water disposal operations are defined for the purpose of this paper as those operations that result in the disposition of dredged material in the open ocean, bays, estuaries, inlet rivers, and lakes. From the standpoint of water quality effects this definition is expanded to include those materials placed on beaches, marshes, along river edges, or any other type of unconfined land disposal in which the placed materials are subject to the influence of tides, river stage fluctuations, or are readily washed back into the water by rainfall. Increased levels of suspended solids, sediment buildup, and oxygen depletion are the environmental effects of aquatic disposal operations that have most frequently been documented. However, many other potential problem areas have not been well documented. Concern over the existence of or potential for long-term or indirect adverse effects on aquatic communities often stems from observed phenomena that indicate the possibility of such adverse environmental effects. In other cases, such concern is often due largely to conceived hypotheses. Regardless of the basis for concern, the potential for long-term adverse effects resulting from open water disposal of dredged material does exist. It is therefore of paramount importance that studies be conducted to provide a better understanding of the causative mechanisms involved and of the nature and significance of any adverse environmental effects. One of the greatest concerns is the possibility of long-term effects on water quality and associated flora and fauna resulting from the open water disposal of materials classified as polluted. As mentioned above, short-term effects such as the decrease in dissolved oxygen have been documented. However, these effects usually result from organic materials (such as sewage sludge) mixed or incorporated into the bottom sediment. The possibility of long-term effects is usually attributed to the presence of other constituents in the sediments such as biostimulants and toxins. Unlike sewage sludge, which is incorporated into the sediment and on mixing can exert a demand for dissolved oxygen, biostimulants and toxins are often chemically or physically sorbed within the sediment matrix. It is generally agreed that constituents sorbed on the sediment particles are not as readily available to the food chain as dissolved materials. The question then becomes, "Under what circumstances and to what extent are the constituent-to-sediment attachment mechanisms altered in ways that could cause the release of constituents to the water?"

It has been estimated that dredged material accounts for 80 percent by weight of all materials disposed of in coastal waters and that the vast majority of this amount is placed in water less than 100 ft deep. Of particular concern are the questions regarding the effects of coastal disposal operations on water quality and the subsequent effects of spoil sites on the structure and function of benthic communities. Because of these concerns, various disposal alternatives have been proposed, one of which suggests that dredged materials should be dispersed instead of confined to a delineated site. Other suggestions include transporting the materials to deeper waters or confining the materials on land. However, there exists little information by which these alternative procedures can be compared and evaluated in all the nation's coastal waters. Therefore, research is being initiated to determine the magnitude and extent of effects of spoil sites on organisms, the quality of surrounding water, and the rate, diversity, and extent of colonization of such sites by benthic flora and fauna. It is generally agreed that, due to seasonal factors and the subtle nature of the changes in benthic communities, on-site long-term field studies are needed to adequately document and assess cause and effect relations. However, because of the high cost of long-term field studies and the great number and diversity of coastal sites, a preliminary survey of all known sites is being conducted. The results of this survey will be used to consolidate all currently available information pertinent to the coastal dumping of dredged material and to design monitoring studies for a few (perhaps six) representative disposal sites. Emphasis will be placed on the assessment of those physical, chemical, and biological factors currently thought to serve as indices of or control factors for benthic colonization.

In order to assess the environmental impact of open water disposal on a case by case basis, methods are needed to predict the physical fate (location as a function of time) of dredged material. To aid in predicting the long-term effects of open water disposal, methods are needed to predict subsequent resuspension of dredged material and its distribution. Several mathematically based simulation procedures designed to predict physical fate of various materials disposed of in open waters are in existence. However, few of these simulation techniques have been developed, modified, or utilized in connection with dredged material disposal operations. Similarly, very little has been accomplished in the development of techniques to predict resuspension and subsequent transport of disposed dredged material. To address this problem, research has been initiated to determine the fate of dredged material by developing techniques for determining its spatial and temporal distribution as a function of various hydrological regimes. Initial efforts in this research area will be directed toward assessing presently available dispersion models and delineating areas for further developmental research. Refinements will be made to present models, and, where needed, additional techniques will be developed. Long-term research efforts will be directed toward the development of techniques for predicting sediment resuspension and transport with emphasis placed on determining those factors controlling or related to resuspension.

As mentioned earlier, one of the primary concerns regarding open water disposal is the possibility of water pollution. Information is needed on the quality and quantity of dredged materials, the method of disposal, and the nature of the aquatic media in which these materials are disposed. In addition, fundamental information is needed on the constituent-to-sediment attachment mechanisms. Finally, methods need to be developed to predict, prior to the disposal operation, the nature and significance of the effects on water quality.

In order to determine the effects of dredged material disposal on water quality, research has been initiated to determine, on a regional basis, the short- and long-term effects on water quality due to the disposal of dredged material containing various contaminants.

Quantitative chemical analysis procedures need to be modified or developed to investigate varying types of sediments. Such analyses include: determination of sediment sorption capacities, determination of ionic and cationic sediment exchange capacities, sediment elemental partitioning studies, and development of sediment leaching procedures. Particular emphasis will be placed on the development of laboratory leaching procedures, verified by field pilot studies, that will enable prediction of the effects on water quality prior to dredging.

In addition to the concern over the possible adverse effects that changes in water quality may have on aquatic organisms due to the discharge of contaminated dredged material, concern also exists over the potential physical effects on the structure and function of aquatic communities. Such effects may be due to physical alterations in bottom geometry, bottom substrate, and current patterns. The current state of knowledge does not allow one to definitely assess these effects or to judge whether they are of an adverse, neutral, or beneficial nature. Research has been initiated to determine the effects on the structure and function of biological communities due to the physical impact of dredged material disposal. Again, initial emphasis in the research program is being placed on laboratory studies designed to define and measure the influence of open water disposal of dredged material on biological communities. These laboratory studies will be used to provide experimental design information for highly controlled field studies to be conducted as a follow-on to the laboratory studies. In all laboratory and field studies, particular emphasis will be placed on gathering information that will define, insofar as possible, cause and effect relationships.

Because of the concern over potential detrimental effects on water quality and aquatic organisms due to open water disposal of contaminated dredged material, the Congress has recently passed legislation requiring the Environmental Protection Agency and the CE to establish criteria that regulate the disposal of such materials. While there is complete agreement over the need for such criteria, there is currently little definitive information available on the effects of disposal of dredged material. Therefore, regulatory agencies faced with the legislative requirement of establishing dredged material criteria must strive to establish meaningful criteria based on the best possible knowledge, and avoid the tendency to set forth criteria that precede the current state-of-the-art. Ideally, the CE envisions criteria that will provide the best possible state-of-the-art guidance as well as serve as a vehicle to generate information which will (a) provide a basis for quantitative evaluation of water quality and aquatic organisms in terms of various use requirements; (b) provide information that would aid resource managers in viewing dredged material as a potential resource; (c) provide baseline conditions of value to the scientific community, thereby hopefully reducing costs of future research investigations; and (d) provide a basis for policy decision making. Recent research directed toward determining the location of pollutants within sediments (elemental partitioning) has indicated that the pollutants are closely associated with fine-grained sediments and organic matter. However, there is only a poor understanding of the specific location and form of pollutants in varying sediment types. Research has been initiated to provide information on the changes that occur in pollutant partitioning during the dredging process as well as the subsequent transport and deposition following open water disposal. Although initially this research will be of a fundamental nature, eventual results will be used to update dredged material pollution criteria and aid in determining the environmental impact associated with dredging operations. Research has also been initiated to develop a leaching test designed to measure that amount of any chemical constituent that, due to dredging, migrates from the solid phase (such as sorbed or crystalline matrix) to the dissolved phase. Such a test is being designed to measure the change in availability of sediment contaminants that might result due to dredging and disposal operations.

Environmental Impact of Land Disposal

Decisions concerning land or open water disposal have, in the past, been based primarily on economic considerations; however, land disposal has more recently been recommended as the preferred disposal method for polluted dredged material because of concern for potential adverse environmental effects. The land disposal alternative has been selected in most instances with a complete lack of knowledge regarding its potential environmental effects. In order to ensure that land disposal is an acceptable alternative to open water disposal and additionally to facilitate public acceptance of land disposal, research has been initiated which will identify and evaluate the broad, basic relationships between the disposal site and all aspects of the surrounding environment.

The disposal of dredged material on coastal marshes is decreasing because of adverse environmental consequences, and it is desirable that this practice be discontinued whenever feasible. It is generally recognized that marshes and wetland systems serve as nurseries, breeding areas, and zones of high biological productivity for coastal zones and nearshore areas; therefore, the disposal of dredged material in these environments is discouraged. There are situations, however, where wetland disposal of dredged material may be the only viable alternative. Research has been implemented which will provide more definitive information on the biological, social, and economic implications of disposal on marshes and wetlands in order to provide guidance to the CE District and Division offices so that material can be disposed with minimal adverse effects.

Examination of existing confined disposal areas and operations has shown that the intent of confinement has infrequently been met, regardless of the desired goals of efficiency, economy, safety, and environmental control. More effective long-term solutions are sought through research aimed at optimizing facility size and shape, weir design, location, and operation, and filling rates and patterns. Both interim and permanent solutions to short- and long-term needs in containment area management and environmental control will be explored, tested, and implemented.

Productive Uses of Dredged Material

Mounting evidence indicates that dredged material can and should be considered as a manageable resource with documented evidence of environmentally compatible disposal operations.[5,6] The potential for environmentally compatible disposal of dredged material in open water includes areas such as marsh creation, spoil island development, beach nourishment, and substrate enhancement.

The loss of coastal salt marshes and wetlands through the combined efforts of both nature and man is fully expected to be a continuing process. The value of these coastal marshes as high productivity food sources, wildlife habitat, and fishing, hunting, and coastal erosion and storm protection areas is only now becoming fully understood. A research program has been designed which will provide more definitive information on the utilization of dredged material for the creation of marshes and spoil islands. The deliberate creation of marshes and spoil islands becomes an attractive alternative to either open water disposal or disposal on marsh surfaces, as a definite need has been established for these types of habitats. These appear to be the most promising concepts which would involve a volumetrically significant amount of dredged material. Most completed research has been accomplished on relatively clean sand in protected areas of estuaries;[6] however, this research effort will attempt to expand these basic concepts to areas in which the consistency of the dredged material or the conditions of the surrounding environment are less than desirable.

The disposal of dredged material in upland areas, on wetlands, and in navigable waterways in many cases results in altered physical and chemical substrate characteristics. While there are known and suspected cases of consequential damage or undesirable changes in indigenous flora and fauna, there are also known cases of beneficial changes and increased biological productivity.[2,3] Numerous unique situations exist in terrestrial, wetland, and water bottom habitats which lend themselves to potential enhancement. For example, flood control structures have restricted or prevented overbank flooding in many riverine and coastal wetland areas with a resulting deprivation of natural nutrient and sediment replenishment. The possibility certainly exists that the controlled disposal of dredged material could be a method of alleviating this situation to some extent. The feasibility of water bottom enhancement through planned substrate alteration is also particularly attractive. In addition to the improvement in sports and commercial fishing through a process analogous to artificial reef construction and the enhancement of benthic communities, there are possibilities for improving bottom topography and for facilitating crop harvesting by coating polluted or undesirable substrates.

Multiple Utilization Concepts
Involving Confined Disposal Areas

It is estimated that there are approximately 200 active CE dredging projects that rely in whole or in part on the confined disposal of dredged material. Additionally, 2,875 hectares of new land are acquired each year to contain the volume of material which is generated solely during maintenance dredging operations. Mounting evidence indicates that the percentage of dredged material that will have to be confined on land will increase rather substantially in the foreseeable future. A basic assumption and theme of this research program is that, in those cases where confined disposal is essential, much of the adverse public reaction as well as undesirable environmental qualities can be mitigated through carefully conceived, planned, and executed multiple utilization schemes. In keeping with the philosophy of the research program, a series of viable alternatives should be available for consideration in the decision-making process regarding the disposal of dredged material.

Multiple utilization involving wildlife and/or fisheries conservation appears to be a most feasible and desirable concept at this time, particularly in regard to the nation's coastal zone. The nature and location of many confined disposal areas make them quite amenable for use as wildlife habitats. The state-of-the-art of game and wildlife management is sufficient to demonstrate adequately the benefits that can be derived through such techniques as water level control and the creation of food, nesting or breeding grounds, and shelter or refuge. Confined disposal areas can and already have, through largely unplanned efforts, provided these desirable conditions.[4] These disposal areas often are the larger tracts of undeveloped and unpopulated land in the midst of spreading urbanization and industrialization. A research effort currently in progress will attempt to optimize the planned utilization of these areas for a wide spectrum of wildlife enhancement while maintaining compatibility with dredged material disposal requirements. Particular attention will be devoted to determining physical environmental requirements for various species' life functions such as breeding, nesting, feeding, resting, and predator protection with the ultimate goal of designing and testing several habitat production concepts in various environmental settings.

The development of public recreational areas emerges as an attractive possibility as a utilization concept that would be applicable to more than a single location and would permit cognizance of regional needs, distribution of dredging projects, and legal and policy constraints. These areas could include waterfront or island parks, amusement parks, camping and picnic grounds, playgrounds, parking areas, and a variety of other uses or activities that are well suited for staged construction on relatively poor foundation conditions. Research efforts are designed to provide a choice of economical, practical, and aesthetically acceptable retention structure designs and to develop dredged material replacement procedures which will be compatible with water quality standards.

Treatment Techniques and Equipment

While little is known of the specific nature of polluted dredged material or, consequently, the effects of land or aquatic disposal, there doubtless will remain many cases where treatment of dredged material is necessary. Treatment of dredged material is at once both similar to and vastly different from the treatment of domestic or industrial sewage. The types of pollutants found in dredged material are, for the most part, the same types found in most domestic and industrial waste. Consequently, the fundamental basis of the processes needed to treat dredged material is essentially the same as that for the treatment of conventional wastes. The major differences lie in the operational procedures. This is primarily because conventional treatment facilities can be designed for usually uniform loading rates and waste characteristics. In the case of most dredging operations, however, tremendous volumes with highly variable characteristics are produced in a short period of time. Full-scale field pilot tests are being designed to determine the technical, economical, and ecological feasibility of treatment in connection with various types of aquatic and land disposal operations. An initial effort is the assessment of presently available chemical, physical, and biological treatment processes. Those processes indicating promise for treating dredged material will be selected for subsequent modification and development. Additionally, laboratory bench studies have been initiated as early efforts designed to provide information on the basic effectiveness of various known treatment processes on varying types of dredged material. Design information necessary to scale up to field pilot studies will be provided.

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13. ABSTRACT

The realization that the dredging and disposal processes are highly complex situations and the urgency of providing definitive information on the environmental impact of current and potential disposal methods, as well as the development of techniques for mitigating potential adverse effects, have led to the development of a comprehensive five-year research program. Due to the fact that dredging and the disposal of dredged material occurs in such highly variable environmental situations, it has been generally accepted that a universally applicable methodology cannot be satisfactorily developed. Consequently, it was concluded that a broad-based program of research was required to provide definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. This research effort will provide solutions to many problems within two years and to some of the more difficult and complex ones within five years. The research plan is by necessity a dynamic one and is under continuous adjustment as more information is developed from early research under this study or from other sources.

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