DREDGING FOR DEVELOPMENT

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Editors

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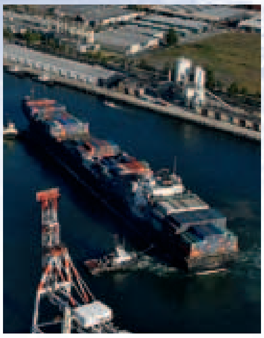
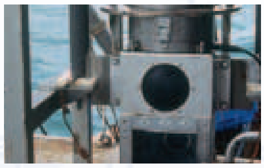
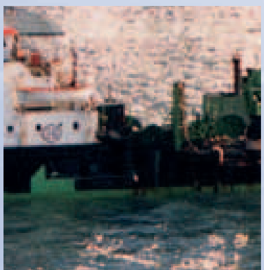
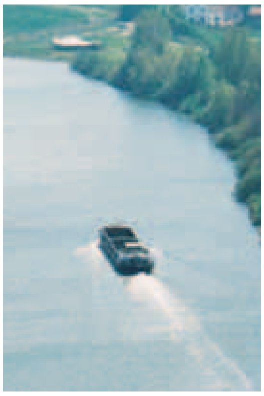
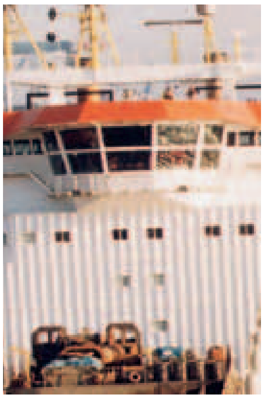








COVER: Collage of dredgers rainbowing for land reclamation.



ACKNOWLEDGEMENTS

This sixth edition of Dredging for Development attempts to update the previous version and in so doing recognise the advances and changes in the dredging industry since 2004. The fifth edition depended on the fine research done by Charles Hummer, Jr. for the fourth edition, and that basis remains the case here. Furthermore, in the tradition of the International Association of Dredging Companies, the former Secretaries General Peter Hamburger and Constantijn Dolmans and their successor Rene Kolman were instrumental in ensuring the continuation of this compact and yet hopefully complete volume and of seeing the necessity for sharing this knowledge worldwide. Numerous dredging experts at the IADC companies also offered their advice and encouragement. The good services of Nicki Clay and Tamsin Watt of HR Wallingford's environmental group have also helped to support the accuracy of the new edition.

Besides the revisions in the text, other changes in this edition include the updating of photographic material to reflect the current state-of-the-art of dredging. These photographs came from a wide variety of organisations, but especially from Terra et Aqua magazine as well as IADC member companies.

Altogether we hope that this edition will be as well-received as the previous editions, and wish to thank all those who have contributed to the wealth of dredging literature and to making this book a useful tool.

Nick Bray and Marsha Cohen
December 2010

PREFACE TO THE SIXTH EDITION

The International Association of Ports and Harbors (IAPH) has long been aware of the need to provide public officials of developing nations with an introduction to the complex field of dredging; one that is written in direct, non-technical language, covers the main elements of which such officials must be aware, and provides a source of basic information and references concerning the field of dredging technology. For this reason *Dredging for Development* was first presented to the IAPH membership and published in *Terra et Aqua* in 1983. Interest was immediate and a second revised edition was published by IAPH as a separate publication in 1987, with another significant revision following in 1991. After much positive response and in order to report on significant developments, IAPH and IADC decided to undertake a fourth and a fifth revised edition, which were published in 1997 and 2004 respectively.

This sixth edition has been made as current as possible and therefore reflects some significant changes from earlier versions. Special attention has been paid to new forms of contracts – with the emphasis on public-private partnerships, alliance contracts and early involvement of dredging companies and stakeholders in a cooperative rather than antagonistic relationship. The fact that in most parts of the industrialised world the identification and resolution of environmental issues are now recognised as essential in developing a dredging project has made it easier to work as partners in creating necessary infrastructure. New references to recent literature have been added and statistical data adjusted.

This publication is not, nor is it intended to be, an exhaustive work to teach how, or even when, to perform dredging. Rather it is meant to highlight some factors and issues that should be considered when dredging becomes a logical or essential part of a port development project. Likewise, we have included some information on the need to consider subsequent operation and maintenance of port projects as it relates to dredging once construction has been completed.

In short, this publication is an introduction to the complexities of dredging. Dredging is essential to the construction and maintenance of navigation and port projects. It plays a role in offshore energy developments, be it oil and gas exploration or the establishment of offshore windmills, and in remediation of contaminated industrial sites. The various aspects of the dredging process, the types of soils encountered on dredging projects, the equipment generally employed, the placement of dredged material, the types and nature of contracting vehicles, the vital importance of environmental balance, including

Finding appropriate dredging solutions is always a high priority. Conventional dredging techniques can be both efficient and economical.

sustainable development and matters related to financing such projects are all issues of which the navigation and port officials must at least be aware.

Whilst there are many publications and sources of information available to those who deal with this field as a speciality, there are few documents designed especially for the managers, planners and decision-makers. They, above all, must have some basis of general information about dredging related issues and knowledge in order for them to direct and focus the actions of their staffs. They must have an appreciation of these issues as they ponder the feasibility of developing navigation projects.

This publication is an attempt at providing a single document for those officials and managers. It is not intended to be all inclusive, for that would take a major publication and one which most busy managers would not likely see or have the time to peruse. It is intended to be readable, available, balanced and used by a wide audience of navigation and port managers, officials, and the public. The publication lists some of the major sources of current information on dredging and port development and also provides the web addresses of organisations and information sources that may be helpful for those wishing to explore the field further.

We sincerely hope that this new edition will provide a useful, up-to-date reference source for officials and managers responsible for port projects. Whilst our primary aim was to provide this information to developing nations, experience has shown that many ports, port users and the public in both developed and developing nations have found this publication useful. As with any publication of this nature, we have tried to maintain a balance of brevity, readability and substance. We welcome your comments and suggestions for changes and improvements.

Comments should be directed to:
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www.iadc.dredging.com, info@iadc-dredging.com

CHAPTER ONE

WHAT IS DREDGING

A simple definition of dredging is that it is the subaqueous or underwater excavation of soils and rock. The process consists of four phases:

- Excavation
- Vertical transport
- Horizontal transport
- Placement or use of the material dredged.

Since the excavation usually occurs underwater, it cannot be seen. Hence, some rather sophisticated technology is employed to visualise the work. To define the quantity or area to be dredged, bathymetric surveys using acoustic sounding techniques are often used. To understand the nature of the materials to be dredged, geological and geophysical exploration methods may be employed. Generally speaking, the nature and complexity of dredging is not well understood except by those actually connected with its uses. In addition, there is sometimes a tendency for people to consider only the excavation phase of the process and overlook the transportation and placement phases, which require equal consideration and emphasis. Alternatively, they may be only interested in the placement (or relocation) stage, ignoring the benefits to be gained or impacts associated with the excavation process. A list of some of the purposes of dredging can be found below. The number and importance of issues that must be considered in the planning, design, construction and maintenance of projects involving dredging, and the fine environmental and engineering balance that has to be achieved, are often underestimated. For this reason, it is prudent here to provide information on the process and description of the potential benefits and impacts.

The Importance of Dredging

From the beginning of civilisation and the evolution of established communities, there has been a need to transport people, equipment, materials and commodities by water. This resulted in the requirement that the channel depths of many waterways be increased to provide access to ports and harbours. Most major ports in the world require dredging at some time to enlarge access channels and turning basins, and to provide appropriate water depths along waterside facilities. Furthermore, these channels often require frequent and regular maintenance dredging. In the case of fluvial navigation, dredging is also required to construct and maintain vital links to inland ports and facilities.

Aerial view of the Port of Melbourne, Australia: As water-borne transportation grows in importance, dredging is an essential tool for maintaining harbour depths to accommodate supersized vessels.

Demographic developments indicate that human involvement with water-related issues will continue to increase with the passage of time. Global population rose to 6.9 billion in 2010, with approximately 3 billion people — about half of the world's population — living within 200 kilometres of a coastline. By 2025, that figure is predicted to double. Thus population is increasing at a rapid rate and, according to current predictions, by the year 2050 world population will have grown to 9 billion. This increase will lead in particular to further urbanisation and, even more importantly, will produce a more than average contribution to over-population in many coastal zones. The average population density in coastal areas is about 80 persons per square kilometre, twice the world's average population density. An increase in coastal populations will place a greater demand on residential, employment and recreational facilities, as well as on beach protection and other health and safety requirements.

The demographic developments highlighted above will have an enormous impact on the need for goods and services. However, in addition to the economic growth purely based on the increase in population, an additional increase in the Gross Domestic Product (GDP) per capita is predicted over the next few decades for many countries. This economic boost is due to further globalisation of markets and to the opening of formerly closed markets by new trade agreements. For instance, it is generally recognised that Brazil, Russia, India and China (the BRIC nations) have changed their political systems to embrace global capitalism. Investment banks predict China and India, respectively, to become the dominant global suppliers of manufactured goods and services while Brazil and Russia will become similarly dominant as suppliers of raw materials, before 2050. Furthermore, the effects of technological developments such as the Internet will also generate an increasing flow of goods and services.

The importance of waterborne transportation of goods will become more obvious and will make it imperative that ports and harbours are accessible to the shipping industry. Waterborne transport has been proven time and time again to be environmentally preferable to overland transport as well as economically viable. Dredging must therefore be an integral part of any infrastructure plan to ensure that ports and harbours, as well as residential and recreational areas, can adequately meet these growing demands. Dredging also has a role to play in the construction and maintenance of hinterland connections.

In summary, dredging plays, and will continue to play, a vital role in the economics of most countries in the world. Maritime transport remains the major route for most commodities and continues to increase. Navigation projects must keep pace with maritime transport needs in order to support and maintain local, national and regional economies. Further information on the role of dredging in the development and maintenance of navigation may be found in Wilson (1996) and Yell & Riddell (1995).

Dredging Objectives

The basic reasons for dredging include:

1. **Navigation:** When the reason is to create or extend harbours, basins, canals, marinas and other facilities the new work is called capital dredging. When it is to maintain existing waterways, harbours and channels, it is generally called maintenance dredging.
2. **Construction and Reclamation:** Dredging can also provide construction materials such as sand, gravel, shell and clay, or provide landfills, including the construction of industrial and residential areas, highways, dams, airports, causeways and habitats for birds and other forms of wildlife.

Rainbowing clean sand for land reclamation.

Kansai International Airport, Japan is constructed on an artificial island made by dredging.

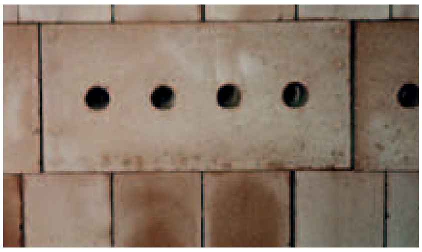
Alicante, Spain, before and after beach replenishment: Dredging is used to repair eroded beaches and damaged coastlines.

3. Beach Nourishment: A third reason is to provide fill material for the protection and replenishment of beaches for recreation as well as for the construction of protective dunes.
4. Environmental Remediation: A more recent use of dredging is to remove or remediate subaqueous pollutants and improve water quality. This type of dredging operation is used as a means to clean-up contaminated waterways or subaqueous facilities, such as settlement or sludge ponds, or mine tailing ponds and rehabilitate 'brownfields', that is, contaminated industrial areas which can then be redeveloped.
5. Flood Control: Another reason for dredging is to improve or maintain the discharge or flow capabilities of the rivers, channels and/or natural waterways by maintaining or increasing the cross-section or by the realignment of watercourses or the construction of control structures such as dams, dikes or levees.
6. Mining: A sixth reason is to recover minerals, gems, precious metals, and fertilisers, or the removal of overlying material to reach such deposits.
7. General: Other reasons include excavating for underwater foundations and for the emplacement of oil, gas or other pipelines or tunnels, and providing for flood control in swampy or lowland areas, where environmentally acceptable. Dredging is also used for maintaining irrigation canals and reservoirs, infrastructure that will become even more important as the world seeks to conserve and use scarce fresh water supplies.

Obviously dredging projects can and do vary enormously with regard to the purpose of the project, and the volumes and types of soil which have to be moved. In developing countries, problems may arise when implementing even small-scale dredging operations, and local, low-cost solutions may be preferable. Suitable dredging equipment that would routinely be available in more industrialised areas is often not present and has to be imported at great expense. The dredging solution should fit the situation and take the needs of local stakeholders into account.

Dredged Material as a Resource

Bricks made from clean dredged material provide a resource for the building industry.



All too often people think of dredged material as dirty, unwanted soil – something that is unclean. This is by and large erroneous. Dredged material is predominantly a clean, re-usable product; in many cases akin to the soil in one's garden, in which vegetables are grown. Dredged material is a resource. Only in some, generally industrialised, places in the world are there appreciable quantities of material that have been affected by industrial contaminants. Where legislation allows, a project developer can easily use clean dredged material in an effective and economical manner. If the material is of a sandy or rocky nature, it may make an excellent fill for land reclamation; if cohesive and muddy it might be used for landscaping or improving agricultural land.

Placement

Often dredged material is the sediment that forms part of the dynamics of the river, estuary or coastline in which it resides. In such cases, it may be preferable to return it to the same sedimentary system at an appropriate location. Whether the dredged material is from a dynamic or static part of a sedimentary system, its relocation and re-use must be carefully considered from an engineering and environmental viewpoint.

Types of Material to be Dredged

Types of material to be dredged vary significantly from project to project and even within the confines of the same project. The primary categories generally associated with dredging are:

- peat and organic soils,
- clays,
- silts,
- sands,
- gravels,
- cobbles,
- boulders,
- broken rock,
- rock and
- cemented soils and corals.

Within each of these major categories are ranges of physical characteristics, such as particle sizes, particle nature, and plasticity. The type of material determines the most effective dredging plant, the production rates, the potential end uses or placement, and the characteristics affecting handling such as bulking, formation of clay balls, etc. The chemical and biological characteristics of the material are also relevant. The type of material has a significant bearing on the environmental effects of the dredging and disposal process. See the PIANC publication, *Report of the International Commission for the Classification of Soils and Rocks to be Dredged* (PIANC, 1984, revision in preparation), for more detailed information.

The Dredging Industry

Since the basic reasons for dredging vary widely, so does the capability to have the work performed. In the case of capital or new work dredging, it is most likely that the work will be done by contract. Dredging equipment involves expensive capital plant investment, specially trained operators and logistical support, as well as experienced project managers. This fact makes it particularly suitable for performance by contractors that are equipped and staffed to accomplish such work and have a proven expertise to do so.

Maintenance work is sometimes carried out by project-owned and -operated dredgers but this is a practice that is generally being phased out as more work is awarded to contractors. Government-owned and -operated dredging fleets have been phased out in many maritime nations, such as Brazil, Germany and Mexico.

Dredging contractors may operate as subcontractors to prime contractors on construction projects where dredging is only a portion of the total construction. Often, on port development or maintenance projects the dredging contractor is the prime contractor. Dredging contractors may be local, regional, national or internationally active, depending on the market conditions. Most large port development contracts require involvement of international contractors in order to secure the widest competition amongst those qualified to perform the work. Generally, the wider the competition, the lower the price, but as will be highlighted elsewhere, the lowest bid does not always result in the lowest overall project cost nor in an optimal solution.

There are a number of very competent dredging contractors active on the international market, and there are some contractors that may only be active in selected international markets depending on the economies of mobilisation costs of the dredging equipment. On very large jobs, it is not uncommon to see contractors join forces as joint ventures for that specific project, although they may continue to compete in other markets. Organisations such as the International Association of Dredging Companies are an excellent source of information on contractors active and available for dredging work worldwide.

For further general reading on dredging and the dredging industry see Bray et al. (1997), Herbich (1992), Richardson (2002) and Eismer (2006).

CHAPTER TWO

THE PLANNING PROCESS

Clearly, a process is required for port development as it relates to navigation and dredging, and this process should be well thought out and understood at the outset. There are many specialised books, reports and papers on the details of schemes successfully implemented for port development, many of which are covered in back issues of IADC's magazine, *Terra et Aqua* (see Appendix B).

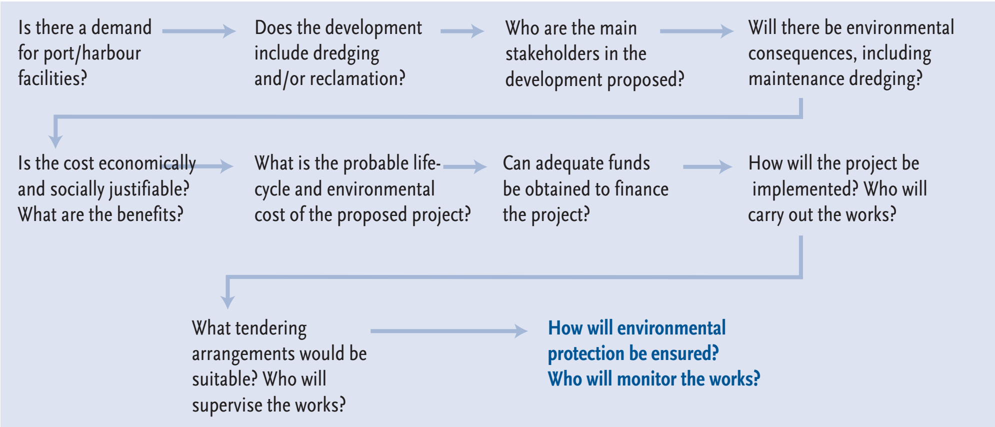
As referred to here in this publication, development refers primarily to the construction or enlargement of a port or waterway. Obviously, dredging is equally important to maintain constructed navigable waterways, but that is an ancillary feature of the development process at this point.

Sustainable Development

Perhaps the greatest challenge in the project development process is the need to consider the project in the context of the environment (see Figure 1). All dredging causes environmental change. Whether it is perceived to be good, bad or indifferent depends on the viewpoint of the observer, or stakeholder, who may be affected by the dredging project. There is, therefore, a requirement to understand and address the concerns of the relevant stakeholders from the outset of the project and to bring the major stakeholders into the development process at the earliest stage. In this way the environmental consequences of the project may be explained, understood and mitigated if necessary, and environmental protection concepts and costs may be incorporated from the beginning of the process.

Lending institutions (see Chapter 9) now require substantive and comprehensive environmental assessments before they will favourably consider applications for development funds. Similarly, these same financial institutions have developed some excellent guidelines and means by which to finance the initial environmental studies essential to sound development (Davis et al., 1990; Bouwman & Noppen, 1996). For a more detailed description of the relationship between dredging and the environment, the publication *Environmental Aspects of Dredging* is recommended (IADC/CEDA, 2008) and *Dredging Management Practices for the Environment: A Structured Selection Approach* (PIANC, 2009). The publications by the International Association of Ports and Harbors that deal specifically with environmental planning and management for ports are also

Figure 1. Bringing the Whole Environment into the Development Process



valuable sources of more detailed information regarding these subjects (IAPH, 2001; Nagorski, 1972).

Consideration should be given to using an integrated or life cycle project management process and structure which involves all parties and disciplines from the outset. Planners; design, cost and construction engineers; dredging experts; environmental scientists; economists; financial planners; and transportation specialists all play a part in the development process. The integrated or collaborative project management process ensures that all these players are involved throughout the process and not only in what is often perceived as their special phases of the project.

The project evolves through the various disciplines but certainly each discipline and phase closely impacts on the others and only through integration of the disciplines will the project avoid oversights and costly errors. Even experienced public works organisations such as the Army Corps of Engineers in the United States and the Ministry of Transport and Waterways (Rijkwaterstaat) in The Netherlands, that have been responsible for port development projects for over a century, have concluded that their efforts could be significantly more effective utilising such an integrated or collaborative approach.

Although there are many formats for the port project development process, for the purposes of this publication a simplified and basic outline is used. The elements of this process are:

Preliminary Planning and Design Financing	See Chapter 2
Consideration of Important Issues	See Chapter 3
Tenders and Bidding	See Chapter 4
Detailed Design Execution or Construction, including Monitoring Operation and Maintenance	See Chapter 5

In some cases, the detailed design, tender specification and execution or construction phases are combined into a design/construction phase. Nonetheless there remain discrete sub-elements even in that case. The remainder of this chapter focuses on the first two of these elements.

Preliminary Planning and Design

Planning is a broad term and appropriately so, for many activities must be taken into consideration during the planning or project formulation phase. Some of the basic elements of this phase are illustrated by the following questions:

1. Is the project consistent with national trade and transportation policies and objectives?
2. On the basis of total transportation infrastructure, does it make good investment sense?
3. Will the project further the national, regional and local socio-economic interests?
4. Is the planning horizon sufficiently long both in hindsight data as well as future use projections?
5. Does it incorporate the latest state-of-the-art in terms of equipment, procedures and throughput taking into account the ability to compete for scarce capital resources?
6. Does it consider alternatives and include an analysis of trade-offs and cost and benefits for each of the alternatives?
7. Does it adequately address the short-, medium and long-term environmental consequences?
8. Are data available from previous dredging works, whether capital, deepening and widening of channels and/or maintenance dredging?

Focusing on the dredging and engineering aspects, consideration should be given to the following:

i. Do adequate data exist relating to bathymetry, morphology, hydrodynamics, geology, meteorology and geography of the potential port development sites?

In a small survey vessel, Niskin water sampler cores help dredgers determine environmental conditions. Site investigations are an essential element for good planning. In addition, the financing of dredging projects are dependent on environmental impact assessments.

LEFT. Both large and small survey vessels are used to measure the dynamics of waterways such as current speeds, turbidity, temperature, salinity and suspended sediment levels amongst other parameters.

BELOW. This remote ecological monitoring of the seafloor (REMOTS) camera is another way of measuring the effects of dredging.

If not, these data sets are essential to evaluate the following: potential design scenarios; proper specifications for the works; good construction estimates; maximum use of natural forces both for construction and maintenance, such as scouring currents; impacts of salt water intrusion; alternative uses of dredged material; and finally, the subsequent maintenance requirements and costs.

ii. Does there exist what is often called, a List of Requirements? Such a list is a quantified assessment of all functions and parts of the project.

iii. Does there exist an adequate engineering staff to collect and analyse existing data, or adequately direct the collection and analysis of such engineering data; or, should consultants be employed? If consultants are to be employed, on which elements should they be used? Often it is advantageous to select a consultant at the beginning who has the capabilities and expertise to carry on through the various phases. This avoids the costs of the repetitive learning curve to bring new consultants on board for each phase. Organisations such as FIDIC may be helpful in the process of identifying suitable firms (FIDIC, 2003 and UNIDO). Sometimes this is not possible and different consultants must be employed for the various phases depending on the expertise required. In any case, this is an opportunity to train local engineers in these specialised engineering disciplines and for them to gain practical experience.

iv. Does the plan consider the use or relocation of dredged material during construction and subsequent maintenance (see Chapter 3)? Were sufficient options considered to minimise transportation costs for the dredged material and to consider the potential impacts of weather, sea state, and other elements on the construction and maintenance processes?

v. In many cases today, a risk analysis or probabilistic analysis is conducted on the project. Using a technique such as a factor tree, the analysis will study which elements or facts result in the highest risk for the project. When the high-risk elements have been determined, the greatest study effort is directed to these factors or elements.

These are rather basic factors, but often the site investigation and data needs, between the planning or feasibility process and the design and construction process, are misunderstood. In many cases, two separate data sets are required. The latter and more detailed is that in the design phase, where such data are essential, to adequately specify the works in such a manner as to avoid unnecessary risk to the owner and to the contractors. There are many instances where preliminary site investigation data were inappropriately extrapolated into designs and specifications with costly and unsatisfactory results.

A water quality monitoring buoy is a good way to capture background data at a fixed location and detect sediment plumes during dredging works.

Once the project feasibility has been determined from the planning phase, a preliminary design is often the next step. It further focuses the development of the project on the most effective engineering, environmentally responsible and economic alternative, and avoids some of the pain of overlooking any critical engineering elements. Further, it provides a productive adjunct to the planning documents required for the successful acquisition of financing. It also provides another series of cost estimates that will be more reliable than those used in early planning documents.

It should be pointed out that cost estimates should evolve and become more accurate as the project development process unfolds. Reliance on only the initial planning cost estimates can be another costly experience. This lesson is one equally applicable to developing and developed nations alike.

Financing

It goes without saying that securing the necessary financing for port development projects is critical. However, if the planning and preliminary design phases are conducted adequately, they provide the necessary basis on which to credibly secure financing for the project. As was pointed out earlier, most lending institutions require substantial consideration of the environmental aspects of development. For example, The World Bank in its well-established publication, *Environmental Considerations for Port and Harbor Development* (Davis et al., 1990), states:

"The World Bank attaches great importance to environmental aspects of development projects. In the case of port and harbor developments, ports and port authorities, consulting firms and Bank port engineers and other staff are expected to provide effective and thorough environmental input into the project concept, preparation, detailed engineering, construction and operation. This implies the need for adequate environmental units within each of the bodies or agencies responsible for the project."

The publication goes on to state:

"The Bank:

- will not finance projects that cause severe or irreversible environmental deterioration without any mitigatory measures acceptable to the Bank...
- will not finance projects that unduly compromise the public health and safety..
- will not finance projects that displace people or seriously disadvantage certain vulnerable groups without taking mitigatory measures acceptable to the Bank...
- will not finance projects that contravene any international environmental agreement to which the member country concerned is a party...
- will not finance a project that could significantly harm the environment of a neighboring country without the consent of that country...
- endeavors to ensure that projects with unavoidable adverse consequences for the environment are sited in areas where the environmental damage is minimised, even at somewhat greater costs..."

Accordingly, in addition to traditional lending institution requirements, environmental aspects must be adequately considered in order to secure financing for port development and improvement projects.

Another important development in financing is The Equator Principles (http://www.equator-principles.com), a voluntary set of guidelines for determining, assessing and managing social and environmental risk in project financing. Since its establishment in 2003, more than 60 international banks have adopted the Equator Principles, including the majority of the world's leading project lenders. The Equator Principles apply to all new project financings globally with total project capital costs of US$10 million or more, and across all industry sectors.

CHAPTER THREE

IMPORTANT CONSIDERATIONS

At this point it is worthwhile to take stock of a number of important considerations, which may well affect the ease with which a project can be implemented as well as the efficacy and viability of the potential dredging development itself.

Identification of Stakeholders

It cannot be stressed too much how important it is to identify the major stakeholders in a project and to bring them into the project development and implementation process as early as possible. Identification of all stakeholders is essential and the effect of encouraging them to "buy in" to a project may eventually make the difference between having a group of partners in development, rather than having a group of organisations in opposition to development.

Environmental Aspects of Dredging Chapter 2 on "Players, Processes and Perspectives" (IADC/CEDA, 2008) provides a broad overview of the development process, seen from the viewpoint of the various "players" in the field. Successful identification and dialogue with the major stakeholders will often lead to partnering, a process which is described in Chapter 9 of the same publication on "Frameworks, Philosophies and the Future", and is briefly described below.

Partnering and Private-Public Partnerships

Partnering is the linking together of the client body with one or more contractors that are engaged to assist the client body with its development. This linking process is designed to set out the common aims and objectives of the partners, to establish the ground rules for working and to set out the responsibilities and risks for each partner. The objective is to foster a climate of mutually beneficial co-operation, where successful completion of the works within agreed timeframes and to agreed standards brings defined commercial benefits to all the parties. This is the so-called "win/win" situation.

Private-Public Partnerships (PPPs) are special relationships developed to bring together two or more organisations having common aims but differing perspectives of what constitutes a benefit. Whereas partnering normally brings commercial benefits to all the parties, Private-Public Partnerships recognise that a Public body may be more interested in the societal and political benefits of a development. These partnerships have to be arranged such that the differing risks and benefits to each party are clearly defined at the outset. In such circumstances the Private Partner might be responsible for assuming the technical risks of the construction methodology, scheduling and commercial factors relating to cost escalation, budget control etc., whilst the Public Body might assume the structural risks relating to permits, political risk and changes in regulatory or design rules. Further reading may be found in Declercq (1999), Janssen (2008), and Tanis and Vergeer (2008).

Employer-owned Equipment

In ports where the administrative agency is responsible for the maintenance of adequate depths in access channels or berthing areas, the question often arises, "what is more economical: dredging done by equipment owned and operated by that agency, or by engaging contractors to do the work?"

This question can only be answered after a thorough evaluation of all the factors involved. The major considerations are the volume and type of material to be dredged; the distance from the job site to the disposal areas where the dredged material will be deposited; the frequency of repetition of the work; the cost of purchasing, maintaining and operating the required employer-owned dredging equipment versus the cost and availability of suitable contractor-owned equipment.

Another consideration has to be the reliability of the employer-owned and operated equipment. The major dredging contractors usually have an extensive fleet of vessels that can be called upon in the event of the designated prime mover being unserviceable. In similar circumstances, the employer operator could be faced with calling in a contractor for an emergency campaign.

It is vitally important to know how much dredging needs to be carried out, and what type it is, in order to achieve the desired result. Is it maintenance, capital dredging or a combination of both? Only by regular hydrographic surveys and density measurements is it possible to establish with reasonable accuracy the main criteria for deciding whether or not an authority should have its own plant.

In the past, many port authorities have relied on a number of loads per week, or hopper tons, to measure performance. These methods do not give a true picture of performance upon which to base a decision as to whether an authority should carry out its own dredging. Frequently, employers operate vessels that are old; they work restricted hours only; and coupled with minimum instrumentation, they do not produce economical dredging.

Employer operators often write vessel costs off at an early stage, and this too distorts any cost comparison that might be made for considering contract dredging.

The employer operator must also take into account at the outset that the vessel purchased could become obsolete if local circumstances change. For example, a change in the disposal area from sea to land (brought about by environmental requirements or the presence of contaminants), or the necessity to carry out capital dredging might then prohibit the existing vessel from operating because of depth restriction or the like.

It is also considered prudent to separate the responsibilities for planning and fiscal control from the actual operation of the equipment itself. Having more or less independent areas of responsibility allows more objective and less intrusive management of the full scope of business and technical operations. In the case of developing countries, these are generally remote from the main centres of dredging and, as a result, mobilisation costs of contractor-owned equipment can be high.

Likewise there may be a lack of dredging experience and skilled personnel. Training and the retention of trained staff can be an expensive proposition as well and should be factored into the analysis of whether to own and operate or contract for dredging equipment. Outside the main centres of dredging, i.e. Europe, Latin America, Japan, China and the USA, there is little training or research in this field.

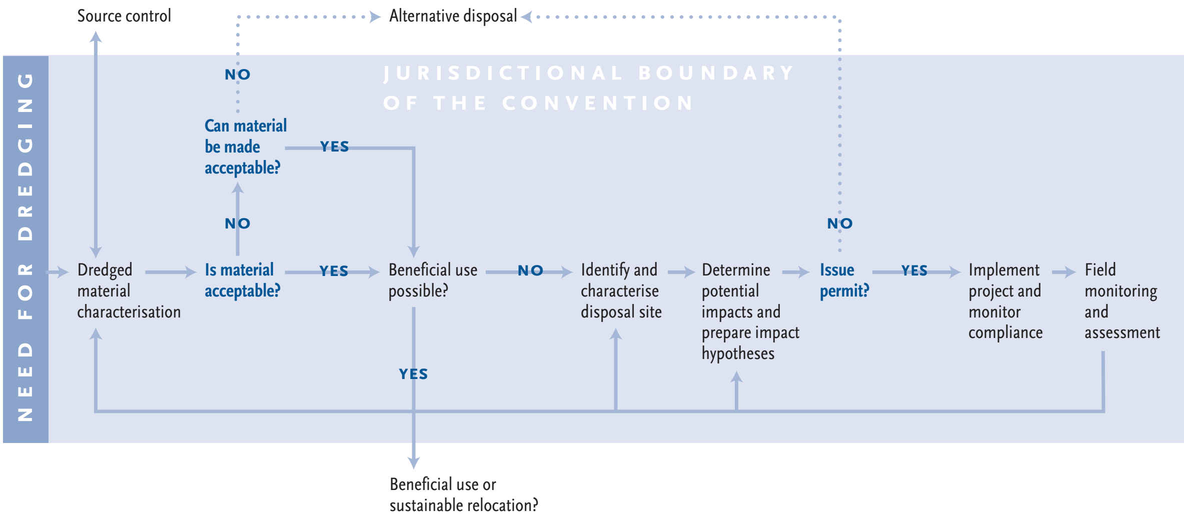
Because of the substantial cost involved in the purchase, maintenance, and operation of dredging equipment, it is usually not economical for port authorities to operate their own dredgers. The trend in most international markets is to move towards privatisation of dredging fleets and the reliance on contractors and competition between contractors to maintain price equity. In addition, dredging equipment normally requires the employment of significant numbers of skilled and unskilled workers, with all the associated expenses of maintaining such a crew. Still, if large recurring volumes of dredging are required, it may be worthwhile for a port to evaluate the feasibility of purchasing and operating its own dredger. But as stated above, this seems to be a diminishing trend. For other contractual intricacies involving equipment see Kinlan, 2010.

Consider Placement Issues Early

The placement of dredged material including necessary licences and permits should be considered early on in the planning process both for construction and subsequent maintenance dredging. Adequate placement sites should be planned and provided for the life of the project. As ports become more congested after their construction and development, continued economic and environmentally responsible placement of maintenance material may well become a problem.

Many projects use multiple placement sites for various segments of the waterway system. For instance, entrance channels may use open water placement sites for both construction and maintenance material. Inner harbours may use intertidal and upland placement sites. In the case of developed harbours, whose sediments are frequently contaminated, specially designed and constructed placement and storage sites may be required.

Figure 2. Dredged Material Assessment Framework (*Adapted from the London Convention*)



The management of dredged material is now a primary consideration for all dredging projects. The location of the dredged material placement site as well as the handling of the material will usually have a fundamental effect on the whole construction process and programme. They may dictate the type of dredger to be used on the project, the manner in which it is used, the environmental effects of the dredging, the possible licences required, the transport and relocating activities, and the consequent monitoring requirements (see below). Dredged material is usually managed (Figure 2.) within the Dredged Material Assessment Framework in accordance with the London Convention (see Chapter 10).

Background Monitoring of Site Conditions

To carry out dredging works in an environmentally acceptable manner it is often necessary to control the works in such a way that environmental disturbance is reduced to a low level. Often this level is related to background levels of environmental parameters measured on the site. This in itself may lead to complications that take some considerable time to resolve.

Many maritime sites are situated in dynamic regions of the coast or in estuaries or rivers. The background conditions at these sites vary continuously from minute to minute and hour to hour, depending on tidal and river flow, wave activity, rainfall and disturbances caused by other natural and man-made events (such as the passage of vessels). There are natural variations at most sites that occur due to seasonal changes in sunlight, temperature and biological activity. Thus to define what is meant by the “background” is no easy matter, even if all the environmental parameters are measured and analysed.

Measurement of environmental parameters, such as current speeds, temperature, salinity, dissolved oxygen and suspended sediment levels, is usually carried out over considerable periods before all the underlying patterns are identified. For a major port development or land reclamation, a period of two years or longer might be considered quite normal. It is, therefore, important to commence environmental monitoring at a very early stage of development, even if the initial monitoring campaigns are restricted to determining which parameters are relevant and their variability. In many navigable waters the bed disturbance caused by deep draft vessels is of a higher level and frequency than that caused by dredging operations.

CHAPTER FOUR

THE DREDGING CONTRACT

As indicated in Chapter 3, a client organisation may decide to carry out dredging works itself, if it has suitable equipment, or it may decide to let a contract to a contracting organisation or it may decide to compare the two alternatives. What is important is that any contracted work is carried out under fair contract conditions, that competition rules are fair and that any comparison between state-owned and private fleets is carried out on a like-for-like basis.

In the majority of cases, the most cost-effective way of having dredging work carried out is to call for competitive bids under international tendering procedures. The free and fair competition implicit in this process has the dual effect of providing a reasonable price for having the work executed and giving the successful contractor a satisfactory return on his investment in plant and personnel. Most unfair or biased tendering procedures, although giving certain temporary advantages to a limited number of favoured contractors, have the long-term effect of making dredging works more expensive, of lowering the quality of work and restricting the development of the local dredging industry.

Considerations for a procurement strategy may include:

- Time: in what time frame must the project be delivered?
- Cost: how important is knowing the final cost before committing to construction?
- Quality: what level of quality is required?
- Complexity: what level of (technical) complexity is involved?
- Flexibility: how likely are changes in requirements or externally enforced changes?
- Risk: what risk allocation is required?

Large-scale dredging projects tend to be complex; they require high quality standards, require flexibility of the team, include considerable risks and are costly. Therefore, the involvement of a qualified and experienced contractor at the earliest possible stage offers advantages. For instance, when the contractor is selected at an early stage, the client and the consultant can benefit from the contractor's knowledge and broad experience – knowledge and experience that a client may be lacking. For small-scale and routine (maintenance) projects, when the client has the necessary knowledge, price usually is the most important consideration. In those cases the selection can be made at a much later stage.

Next to traditional ways of contracting, Partnering and Alliance contracts have become more and more in use for the large-scale dredging projects. Partnering in itself is not a special type of contract. A partnering charter may run parallel to a traditional contract providing guidelines to the relationship amongst the various partners (Athmer, 2005). Alliancing is sometimes seen as an outgrowth of a partnering relationship which results in a legally enforced contract (Janssen, 2008).

Tenders and Bidding

Basically there are three stages in the tendering procedure:

- Prequalification
- Issue of tender documents
- Receipt and review of tenders.

The prequalification stage is not always followed but it is advisable in many cases. It involves the interested contractors providing evidence of their qualifications prior to accepting tenders. Guidance on suitable forms for prequalification is given by FIDIC (see also Brown, N. 2006).

The next two stages are self-explanatory. Regardless of the type of tender procedure used, it is important to point out that the lowest tender or price may not necessarily be the most advantageous for the employer. For instance, the working methods proposed and the evaluation of risk are also important considerations. Generally, bidding for dredging contracts is identical to bidding for civil engineering construction contracts, i.e., in the form of competitive tendering on the basis of tender documents made available by the prospective employer and drafted by the employer or by consulting engineers appointed by the employer. (See FIDIC Tendering Procedures.)

The tender documents usually set out in detail the various conditions applicable to the tender procedure itself, and the contract conditions that will govern the relationship between the employer and the successful tenderer, regarding the execution of the works that are the subject of the tender procedure. Sufficient information must be provided, as a result of the design, to describe clearly the elements of the works and present to tenderers the data and information required for the preparation of a responsible tender. It is generally true that the more detailed engineering information available and specified, the less risk the contractor has to include in the price to accomplish the work. This can have the effect of lowering the cost of the project by shifting the risk and initial engineering costs to the client or owner.

When starting tender procedures, employers and consulting engineers should be aware that the fewer details given and the more vague the specifications and information contained in the invitation to the prospective tenderers, the greater the risk that irresponsible bidders will participate. The smaller the risk to be borne by the contractor, the better the comparison of the various tenderers can be effected.

If the risks remain difficult to evaluate, some marginally qualified contractors may offer the lowest prices, because they cannot anticipate the risks. Then, if certain risks materialise it may transpire that the contractor is not able to bear them, and the damage for the employer may be enormous. In this context, it should be noted that collecting the most extensive and complete information about soil conditions may be costly, but it will pay for itself and often leads to the most economical contract price with the least amount of surprises and risks (see Kinlan and Roukema, 2010).

Nonetheless, there certainly will be instances where the marginally qualified contractor gambles successfully and consequently has a realistic price, in spite of the fact that the employer has not given sufficient information.

Since dredging works are subject to the influence of external factors such as climatic conditions or navigational requirements, which may prohibit the uninterrupted use of the dredging equipment, it is common to find that rates for idleness due to passage and berthing of vessels are included. However, the costs of weather downtime are usually included in the dredging costs as a contractor's risk.

CONTRACT RATES, UNIT COST OR LUMP SUM

The majority of tenders for dredging works incorporate bills of quantity. Such bills consist of lists that specify, sometimes in great detail, the various types of dredging and other activities that the contractor is required to perform under the contract to ultimately achieve the completion of the works.

Also in the majority of tenders, such bills of quantity state the estimated quantities for the items listed (these estimates are not necessarily accurate) and the tenderer is obliged to quote rates for such items per unit and consequently for the entire estimated quantity.

In such cases, it is the rule that the rates in total represent any and all activities to be performed by the contractor and represent the contract price, provided that deviations from the estimated quantities cause a proportionate increase or decrease of this contract price.

The risk for the quantities is borne by the employer. Nevertheless, the contractor may still face a certain risk, particularly if the real quantities are less than those estimated.

The contractor has to carefully calculate rates, taking into account the contract conditions and the work that is to be performed, including the evaluation of costs for materials, plant and equipment, fuel, labour costs, and so on, and any other expenses that may be incurred, including fees, royalties, taxes, and so on. Therefore it can be argued that the unit prices offered in the tender equate to lump sum prices. Of course, this is especially so if the employer requires the contractor to accept the risk for the correct evaluation of the quantities, rather than allowing the quantities to be re-evaluated in the light of what is encountered on site.

The purpose of the lists of unit rates per item is to facilitate the calculation of possible modifications or variation orders. Sometimes tenderers are requested to quote lump sum prices for the completion of the works. In other cases, lump sum prices are only demanded for certain well-defined items, such as mobilisation and demobilisation of the dredging equipment.

COST PLUS AND CHARTER CONTRACTS

Although not often the case, cost plus contracts can be the subject of tender procedures. Examples of this situation are where certain costs are subject to limits, or where the exceeding of certain agreed milestones may trigger limitations to the payment of all costs. The main difference between cost plus and charter contracts is the responsibility for management.

This responsibility resides with the contractor in a cost plus contract and with the employer in a charter contract.

ALTERNATIVE TENDERS

Parties involved in tender procedures must be aware of the possible challenges arising from the submission of so-called alternative tenders. Apart from the complications of comparing such tenders with the conforming ones (often only the prices can be compared whilst technical evaluations may be highly complicated), it must be emphasised that such tenders may fundamentally alter the allocation of risks and liabilities between the parties to the contract.

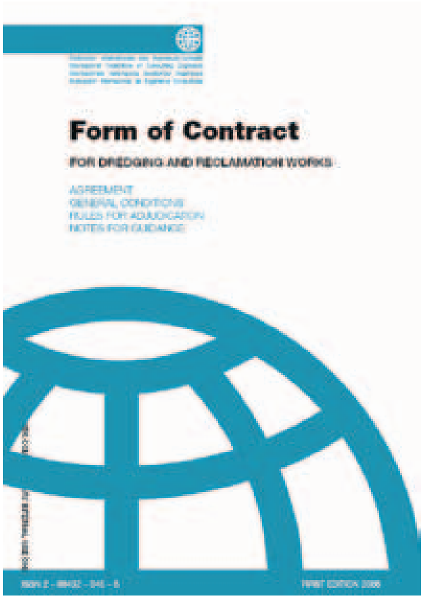
There are, however, cases where such alternative tenders may include procedures or techniques overlooked by the employer and which can result in significant savings. It should be noted however, that good commercial practice dictates that the alternatives developed are the exclusive property of the party that develops the alternative. In short, alternative tenders may have distinct advantages and disadvantages and need to be given special attention.

INTERIM MEASUREMENT AND ACCEPTANCE

It is important on very large projects, where high siltation or erosion rates occur, to develop a method of measurement and acceptance of completed sections in order to establish an equitable and clearly understood means by which to define completed areas and the method used to pay for maintenance of such.

In other words, maintenance dredging may be included in the construction project to enable full project dimensions to be available upon completion of the project, and this factor should be clearly delineated in the contract documents.

Conditions of Contract



Internationally, dredging contractors are faced with a multitude of contract conditions that frequently are drafted locally on the basis of national laws, statutes, attitudes and usages. In many cases, however, where contractors are invited to tender for works in other countries, contract conditions are used which are partially or completely in conformity with internationally accepted standardised conditions such as the FIDIC Conditions.

In 1999 FIDIC published four new standard forms of contract, covering the overall construction industry. The form that was intended to be used for the dredging industry, the so-called Red Book (FIDIC, 1999), created in the eyes of the dredging contractors some major problems because of its extensive size, inconsistent wording and lack of attention to the special needs of the dredging industry. Therefore FIDIC, in close cooperation with IADC, developed a special *Contract for Dredging and Reclamation Works*, which was published in 2006 (see also Brown, N., 2006).

In 2006 the FIDIC (Fédération Internationale des Ingénieurs-Conseils), working with the IADC, developed the publication *Form of Contract for Dredging and Reclamation Works* to provide a straightforward document which contains commercial provisions for this type of work.

RISK ALLOCATION

When entering into contracts, the most important issues, apart from the specifications of the works, are the contract price and possible escalations (including the introduction of variations), the completion date, and the allocation of the risks and liabilities between the contractor and employer. In this connection, the role of the supervisory functionary, which in the case of FIDIC is the Engineer, requires close scrutiny. In the following paragraphs some aspects of the allocation of risks and liabilities will be highlighted, but this is in no way intended to be all-inclusive. For instance, design and construct contracts are different.

Under the general FIDIC conditions, the Engineer performs the supervisory task. In the majority of cases, this is the same person (private or legal) who designed the works and this is apparently the presumption on which the FIDIC conditions are based. In view of the powers given to the Engineer, including quasi-arbitral tasks, it is also of extreme importance for the employer and the contractor that an experienced and capable Engineer be appointed. This is very important as the Engineer is not a party to the contract and therefore if the Engineer were to default, prosecution is only possible in the case of guilt because of tort.

ROLES OF ENGINEER AND SUPERVISOR

When the tender documents are issued, the contractor should be advised who is to act as Engineer or supervisor. The latest edition of the FIDIC conditions stipulates that the replacement of the Engineer can only be effected with the mutual agreement of the Employer and the Contractor.

It certainly is not the intention of the FIDIC conditions that an employee of, or a person directly dependent on, the Employer is appointed as the Engineer. The FIDIC conditions are based on the assumption that the Engineer is notionally independent from both the Employer and the Contractor and must act fairly.

Other contract conditions used in the international field allocate the supervisory task to an agent of the Employer. In such cases, of course, the question of impartiality is moot, but if the parties are completely aware of this situation it does not necessarily create problems. In the event of disputes about a decision of the supervisor, one may enter into mediation, or arbitral or judicial procedures may be taken immediately. In this connection, it is useful to mention that the International Chamber of Commerce (ICC) has developed special rules for an arbitral referee procedure that can be considered more adequate than full arbitral procedures in certain cases.

SOIL CONDITIONS

The soil conditions encountered at the site often cause problems, especially in the case of dredging works. As a general rule it seems acceptable that the contractor bears the risk for the soil, provided that the condition thereof could have reasonably been foreseen and provided the information was correct and reasonably complete.

To judge whether the above provisions have been fulfilled, however, it must be taken into account that in the majority of cases the employer and/or advisors have had sufficient time to acquire the essential knowledge of the soil conditions, whilst bidders to a contract have a very short period to familiarise themselves with the characteristics of the site (Kinlan and Roukema, 2010.)

VARIATIONS

Another problem under dredging contracts may arise from variations. In dredging works there often exists a close relationship between the type of work to be executed and the plant and equipment required for this execution. The introduction of variations, which fundamentally alter certain characteristics of the work, may result in the necessity to mobilise other equipment. The possibility to make variations consequently requires special attention and sometimes should be limited.

DESIGN DEFECTS

Problems may arise due to defects in the design. The parties responsible for the design, albeit the Employer or the Engineer, will sometimes deny that problems are a result of defective design. It is therefore recommended and emphasised that the parties take care that the progress of the works, and any problems encountered, are regularly and timely documented as completely as possible in mutual agreement.

DEFINED RISKS

Contract forms, such as the general FIDIC conditions, as well as other standardised contract conditions allocate most of the risks and liabilities of the execution of works to the Contractor (generally the only exception is the liability for defects in the design and to a certain degree for deviating soil conditions). Some other exceptions are categorised in the FIDIC conditions namely the "Defined Risks". Such risks are to be borne by the Employer to a certain degree, and different phenomena, such as forces of nature and atomic warfare, are listed as such. In the Form of Contract for Dredging and Reclamation Works, the Employer's and Contractor's liabilities are spelt out in detail.

LIQUIDATED DAMAGES

Parties to dredging contracts must be aware of the function of a system for liquidated damages. Generally, such damages can be claimed by the Employer if the works or sometimes specified parts of the contract are not completed within the contractual period. The levying of liquidated damages, however, does not always exclude the possibility that other damages can be claimed by the Employer or third parties.

COMPLETION AND ACCEPTANCE CONDITIONS

Completion and acceptance procedures must be defined in detail, as should payment arrangements and final account procedures. In this respect, it is important to point out that the rules applicable to the submission and return of bank guarantees should be well defined. It is rather unusual to incorporate in dredging contracts a defects liability (formerly called maintenance) clause. In the majority of cases the contractor cannot be required to accept any liability for defects in the works after completion. The pattern of currents in the water, the phenomenon of siltation, and so forth, may change the works and often cannot be attributed to a shortcoming of the contractor but rather to a possibly defective design. Of course, special terms and conditions can be agreed in this respect but they should be adapted to the peculiarities of the work in question.

ENVIRONMENTAL ASPECTS

Contamination and pollution problems are increasingly requiring the special attention of designers, employers, and contractors. Detailed knowledge of local laws, statutes and of international treaties relating to the environment is required. The parties to a dredging contract should carefully determine the responsibilities, risks and liabilities involved. Methods to avoid pollution must be defined as well as the costs thereof. Possible indemnifications should be considered as well as possibilities offered by insurance to cover ensuing risks. Developing an Environmental Management Plan (EMP) and engaging an Environmental Manager with specific expertise about these issues may in some cases be prudent and worth specifying contractually.

INSURANCE

In most dredging contracts, conditions are specified for the insurance of risks for various categories of events causing damages to the parties of the contract or to third parties. Apart from the allocation of risks and liabilities between the parties, careful consideration of joint insurance possibilities and the cost thereof may offer benefits to both parties. The *IADC Users Guide for the FIDIC 4th Edition of the Red Book* (IADC, 1990) still gives valuable information to those who are involved in drafting and executing contracts for capital dredging.

For safety and efficiency in busy harbours, such as Hong Kong pictured here, dredging contractors should be advised of shipping traffic patterns and shippers should be warned of impending dredging activities.

Continuity of Shipping Operations

The Employer should, prior to commencement of the project, advise the Contractor of the normal schedule of shipping movements that may be expected. This can then be accounted for in the price or a special provision clause provided and payment made for delay time that could not have been reasonably expected or assessed.

It is important for the Employer to review its shipping movements so that the Contractor may be advised and economic use can be made of the dredging equipment and time. Special arrangements might be necessary where a particular berth has an unusually high volume of movements or for the likes of Roll On, Roll Off (RO-RO) berths which are likely to have frequent scheduled ferry sailings.

The location of the dredging area and possibly the placement area may have a bearing on the type of vessel to be used. Stationary dredging vessels may need to be "spudded" thus avoiding anchor wires interfering with shipping movements. Likewise, if using a cutter suction dredger (see Chapter 6) and placing the dredged material ashore, the use of a sunken pipeline could be necessary to allow vessels to pass unhindered. Prior to commencing operations, it is frequently a statutory requirement that notices to mariners are promulgated to warn shipping and/or the public of the possible location of the dredging vessels and what action they are required to take. Normally the port authority would advise pilots and shipping on VHF radio of any underwater operations or potential hazards.

Whenever applicable, the Contractor should also be informed if there is a possibility during the time the work is being performed that other persons or contractors could be working in the vicinity and that shipping operations will proceed as usual. The Contractor should be required, therefore, to so plan and conduct operations so they can be done in harmony with, and not unnecessarily interfere with, or endanger shipping and other persons working in the area. All temporary obstructions within the designated work site such as anchors, anchor pontoons, pipelines and the like should be clearly marked and illuminated.

Inspection and Measurement of Operations

The Contractor should be required to furnish such facilities and give such assistance for the inspection as the Engineer may direct, and shall secure for the Engineer and the Inspector free access to all parts of the plant. Transportation should be provided for the dredging Inspector to and from a convenient shore-landing at the beginning and the end of each work period.

RECORD KEEPING

The Contractor should provide to the Engineer or nominated representative, at such times as may be reasonable, sufficient records so that the works may be supervised and monitored. It is important for both the Contractor and Employer (particularly when operating own plant) to keep accurate and contemporary records of hours worked, locations, quantities removed, delays incurred, and instructions received or given in order that performance can be accurately monitored. In the event of claims arising, sufficient agreed information will then be available for both the Contractor and the Engineer to fairly resolve any dispute.

It is also advisable to keep accurate weather, tidal and current information that may become available so that upon completion of the works an analysis may be carried out and compared with the original estimate for the work. This information could be of use when deciding on the timing of future campaigns and/or the type of plant to be used.

Dredged material should be placed at sea according to the regulations of the proper authority having jurisdiction, or relocated elsewhere with the written permission of the owners of the placement area and the requisite permits. If dredged materials are allowed to leak into or be deposited in navigable channels or any place other than the designated deposit or placement area during removal or transportation, the Contractor should be required to remove the materials at the Contractor's expense.

Permits for Dredging Operations

National authorities may require the responsible body to secure a permit for dredging operations in accordance with international conventions (see *Environmental Aspects of Dredging,* Annex A, IADC/CEDA, 2008). In such cases, the requirement should be identified and complied with before the Contractor or agency-owned dredger is allowed to begin operations.

Permits for dredging operations usually fall into the following categories:
- Planning permits,
- Environmental impact assessments or statements,
- Placement permits and
- Mining permits.

Planning permission is obtainable from the relevant body and would normally be obtained by the Employer at the conceptual stage. The relevant competent authority would take into account considerations such as the overall effect on the country or community, possible detrimental environmental effects, and possible alteration of the existing regime and its effect on neighbouring sites.

Within the EU, USA and many other countries, it is required that, prior to granting approval for most capital projects, an environmental impact assessment must be carried out. Also, various bodies such as wildlife and nature conservancy bodies need to be consulted and, on occasion, public enquiries held.

Placement permission is usually required in the industrialised world in the case of placing dredged materials at sea or placing them on shore. Developing countries may have the intention, but frequently do not have the organisation or the financial backing, to enforce the proper licensing of placement areas.

The licensing authority would, in the case of sea placement, generally consider factors such as water depth, currents, volumes of material to be disposed of, nature of material and the degree of contamination, if any, and the local ecology of the receiving environment including fishing in order to specify the permitted location for placement.

Full particulars of the vessels engaged in placement would be required with regular returns being made to indicate the quantity placed, the nature of the material, and the source. As environmental consciousness is increasing worldwide, regulations pertaining to the relocation of unusable materials are becoming far more stringent. Bear in mind, however, that most dredged material is usable.

Shore placement is regulated in a similar manner to sea placement, and generally samples from the proposed dredging location are required to be chemically analysed prior to permission being granted.

Many countries have statutory bodies monitoring and/or licensing dredging and placement projects to ensure there are no detrimental effects on sea defences, safety and navigational depths and that projects have no adverse environmental impact.

It is worth noting that, at the time of the initial site investigation to establish the dredgeability of the material and the economic viability of the scheme, suitable representative samples should be collected. They should be stored for use and analysis when the time comes for applying for placement permission. Particular care should be taken regarding the storage and preservation of samples to ensure *in situ* conditions are maintained insofar as is possible.

Many countries regulate the winning of reclamation and/or construction materials from rivers or the seabed. Frequently, the licensing authority will require payment of a royalty before permission is granted to remove materials such as sand and gravel from the seabed.

CHAPTER FIVE

THE DREDGING PROJECT

Dredging projects are normally classified into capital, maintenance or remedial dredging. If dredging is to be carried out in a new location, and in material that has never been dredged before, it is normally referred to as a capital project. Maintenance dredging is usually recurrent, even if a number of years pass between consecutive dredging campaigns. Remedial dredging is the term given to projects where the removal of the material is to be carried out purely for environmental reasons, to improve the quality of the site in some way. This often entails the removal of contaminated soils.

Detailed Design

This phase presumes that all feasible alternatives have been considered, and a single project has been identified which meets the economic, financial and environmental criteria established. The preliminary design is then developed into a detailed engineering design package.

Capital dredging often involves the creation of new land for residential and industrial purposes.

For the purposes of this publication, this detailed design package is the primary vehicle for developing a set of specifications suitable for soliciting international tenders from dredging contractors. Furthermore, at the end of the detailed design, a reliable cost estimate should be in hand on which to base an evaluation of such tenders.

There are a number of very important elements in the detailed design process. A few particularly significant points are described here.

SITE INVESTIGATION AND DREDGED MATERIAL CHARACTERISATION

The determination of types of materials to be encountered in a project is made by the use of subsurface exploration, geophysical, chemical and biological techniques in which a representative set of samples is taken throughout the potential or actual project dimensions. Since there is often vertical as well as horizontal distribution of material, samples are normally taken vertically to a level at least one metre below those depths planned for the project. These samples are then subjected to laboratory investigation to supplement their characterisation with that from the visual observations usually taken at the time of sampling. There are significant risks involved when insufficient soil characterisation data are collected (Kinlan and Roukema, 2010).

It must be emphasised that the geological or subsurface exploration taken during the feasibility or planning phase is generally insufficient for the level of detail required for the design and construction phase. These detailed sampling or exploration programmes are required once the project alignment and definition approaches that which will ultimately be built. The difference in the level of detail and the need for two occasions of exploration with their significant costs must be emphasised and understood by those in management in addition to those on the technical staff.

The costs of the two phases of site investigation, although not insignificant, are relatively minor in comparison with the overall project costs and are an essential expense if the risk of large and unpredictable cost overruns is to be avoided (Costaras, M.P. et al., 2010).

TOP. Maintenance dredging projects, such as deepening shipping channels, usually occur at regular intervals.

ABOVE. One beneficial use of dredged material is shown at this project in Belgium which used dewatered and treated silt for landscaping.

FREQUENCY OF DREDGING OPERATIONS

In maintenance dredging projects, the required frequency of dredging operations can be readily determined by taking periodic soundings to determine the rate of siltation that is occurring in a given area, under normal weather conditions.

It is often preferable to dredge to a depth substantially in excess of the required minimum in order to allow for siltation to take place for a longer period of time, thus reducing the frequency of the dredging operations and the need for costly repetitive mobilisation and demobilisation of the equipment. However, in some cases the proximity of adjacent structures may make such a procedure impractical.

Strategically located silt traps are a means of concentrating the siltation, and thus the dredging, to a predetermined area that is easily accessible for the chosen dredging equipment. This can be particularly helpful in reducing the risk of sand bars forming.

In addition to periodic soundings, density readings should be taken in order to establish at what point the silt becomes a hazard to navigation. A number of ports now define navigability in terms of bed density levels. It is worthy to note that not all dredging has a positive effect and when an unnatural regime is imposed this may have a short- or long-term adverse effect.

Of course, referring to data collected from earlier dredging activities in the area, whether they have been for capital or for maintenance works, is always advisable.

PLACEMENT OF DREDGED MATERIAL

The ultimate step in the dredging process, if the material is not to be recycled, is to place, relocate or deposit the material in a location away from that where it was excavated. There are a number of placement alternatives.

For uncontaminated material, the basic options are:
- open water
- intertidal and upland, or
- hydraulic fills onshore.

The option or options employed depend on a number of factors, such as:
- accessibility to the work site
- type of dredger and transport system
- whether the dredged material contains contaminants
- costs, and
- environmental factors.

It is always desirable to use the dredged material for beneficial purposes when possible. Such purposes may be to create land rapidly for subsequent construction, use as aggregate, create wildlife habitat, construct shore protection features, nourish beaches, fill abandoned mine or quarry excavations or even, when the material is suitable, use for topsoil. When used for beneficial purposes there is generally a cost-benefit to be achieved, thereby reducing the actual costs of the dredging.

If uses of the dredged material are not possible, either because of the nature, volume or contamination of the dredged material, then placement should be conducted in a manner which creates minimum environmental damage, is cost effective, and for which sites can be reasonably acquired. In many cases it may be possible to recycle the material in the sedimentary system from which it was excavated.

Execution or Construction

In order to move into the execution or construction phase, as was mentioned above, detailed specifications and contracting documents must be prepared and used to solicit tenders for the actual construction of the works. Chapter 4 described in detail the typical provisions and conditions for such contracting documents. Of note is the need to designate an "Engineer" and "Contractor's Representative" by the owner.

In some cases, the Engineer's role is performed by a qualified, knowledgeable and responsible consulting engineering firm. The selection of such a firm is another process that requires due care and attention. On the basis of the tenders, evaluation is made and a contractor selected for the execution of the works. Of particular note is the need for the owner to ensure that an adequate contract administration structure, and construction inspection scheme, is in place prior to the initiation of the execution or construction phase.

Monitoring During the Contract

It is frequently the case that the Contractor must undertake monitoring during the works. This may be required under the contract or as a condition of the permitting. Monitoring may take the form of bathymetric surveying, both at the excavation and placement sites, to check that dredging and placement are being effectively controlled. In addition, suspended sediment monitoring may also be required to ensure that plumes of suspended sediment arising from the dredging or placement works are acceptable.

Operation and Maintenance

The completion of the execution or construction phase provides the physical assets of the project. There is a need to have developed, and to put in place, an operations and maintenance scheme for the completed project and a clear definition between the construction, and operation and maintenance phases must be made. A management plan supervised by a dedicated management officer can support this.

On large projects, where segments may be accepted "as complete" by the owner, maintenance may even be required on the completed segments before completion of the entire project. Much of what is required for such a scheme can be drawn from the planning and engineering phases. But in the case of dredging, there seems to be a tendency to overlook or minimise the importance of subsequent maintenance.

Maintenance costs can be significant and are recurring. Unless provision has been made to adequately maintain the project, its use will be limited over a matter of time as natural forces such as siltation reduce project dimensions and limit the use and effectiveness of the project. It is obvious that such limitations will seriously impact the ability to meet financing obligations and the primary project purposes. The maintenance scheme should include not only the main navigation features, but structural features such as breakwaters, groynes, navigational aids and the like.

CHAPTER SIX

EQUIPMENT CONSIDERATIONS

The reader will discover that there are a variety of dredgers and means by which to employ them depending on the specifics of a particular project. No single type of dredger or system of employment will be suitable for all projects.

The quantity and type of material to be dredged, placement or relocation alternatives, availability of equipment or cost of mobilisation, or accuracy are some of the many factors that play a part in the ultimate choice of dredger (*Construction and Survey Accuracies,* Rotterdam Public Works, 2001). This section presents an overview of the subject.

Types of Dredgers

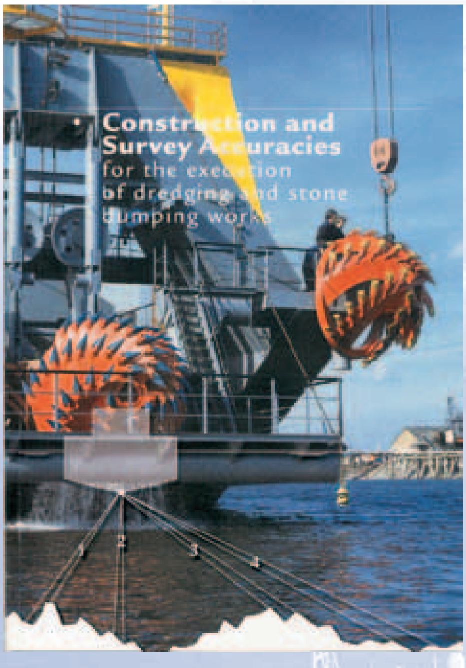
There are a number of schemes for describing types of dredgers. For the purpose of this publication the types of dredgers are described by four broad classifications on the basis of the mode of excavation and operation:

- Mechanical dredgers
- Hydraulic dredgers
- Mechanical/hydraulic dredgers (utilising both basic elements in some combination)
- Hydrodynamic dredgers.

Within these four categories further subdivision can be made on the basis of propulsion, that is, those that are self-propelled either during the excavation phase, the transportation phase or both, and those that are stationary.

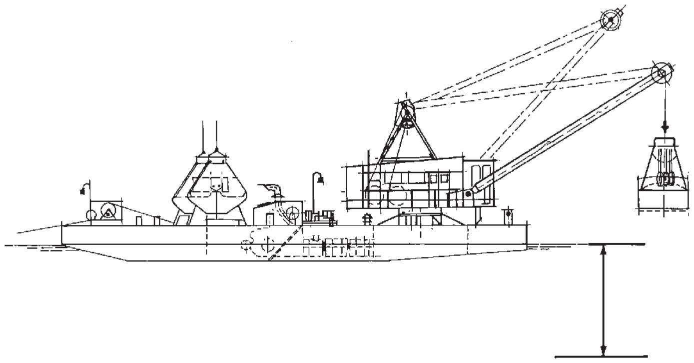
Production rates for dredgers vary widely depending on the circumstances, the material to be dredged and the transport and disposal methods employed. Other factors, such as weather and sea state, ship traffic, depth and thickness of material being removed, also affect dredging production rates. Production rates can range from 50 cubic metres to 5,000 cubic metres per hour or more. For further information on this topic see Bray (1997).

Construction and Survey Accuracies for the execution of dredging and stone dumping works emphasises the need for mutual understanding about dredging requirements.



Mechanical Dredgers

This category uses mechanical means for the excavation of material and is generally similar to equipment used for dry land excavation. Examples of mechanical dredgers are:



Drawing of a grab dredger.

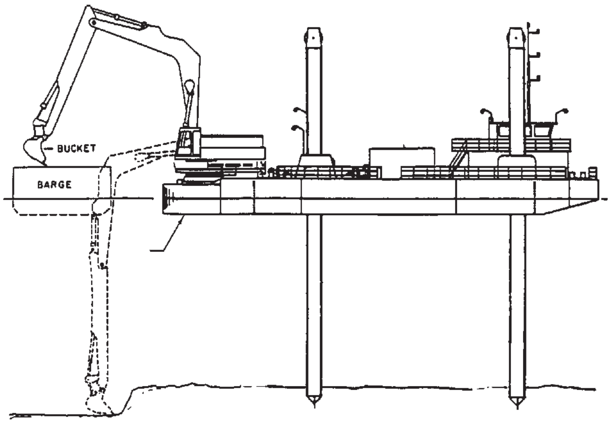
GRAB (OR CLAMSHELL) AND DRAGLINE

These have either rotating cabs or fixed A-frame type barge-mounted equipment. They have hoisting and control systems and use clamshell digging devices or buckets rigged on cables to excavate the material from the bottom and transport it vertically out of the water and into barges for subsequent transport to the placement area. Clamshell dredgers can be used in sands, some types of clay, gravel, cobbles and occasionally broken rock. They are not particularly effective in fine silts, which have a tendency to run

A grab or clamshell dredger mounted on a rotating cab.

BELOW LEFT. A grab bucket attached to a hydraulic machine.

BELOW RIGHT. Close up of a grab.



TOP LEFT. Drawing of backhoe.

TOP RIGHT. Close up of a backhoe bucket.

ABOVE. Backhoes are often mounted on specially designed pontoons.

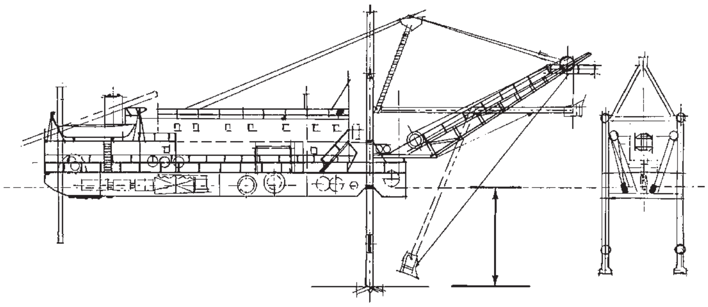
out of the bucket. They are nonetheless used for this purpose in smaller jobs or when fitted with special sealed buckets.

One advantage of clamshell dredgers is their ability to dredge in fairly deep waters and their ability to do precise spot dredging either to remove isolated areas above grade in the navigation prism or along docks and corners of docks. Depending on the type of material dredged, they have moderate to low production rates. They are normally stationary and are fixed at the excavation site using anchors or spuds.

BACKHOE

The backhoe is common to dry land excavators and is increasingly being employed for dredging. As in the case above, it is barge-mounted for dredging, generally non-self-propelled and can have a moderate production rate. Backhoes employ an articulated excavation bucket mounted on an articulated boom. They use hydraulically operated rams for movement, positioning and excavating. The material is excavated, brought to the surface and placed in barges for transport to the placement area.

They can dig a broad range of materials such as; sand, clays, gravel, cobbles and fractured and un-fractured moderately strong rock. They have radius and depth limitations but with some newer models excavating depths in excess of 30 metres are possible. These dredgers are generally stationary and require spuds, or occasionally anchors, to fix them at the dredging location.



Drawing of a dipper dredger.

Dipper dredgers are particularly suited for dredging boulders and stiff clays.

DIPPER

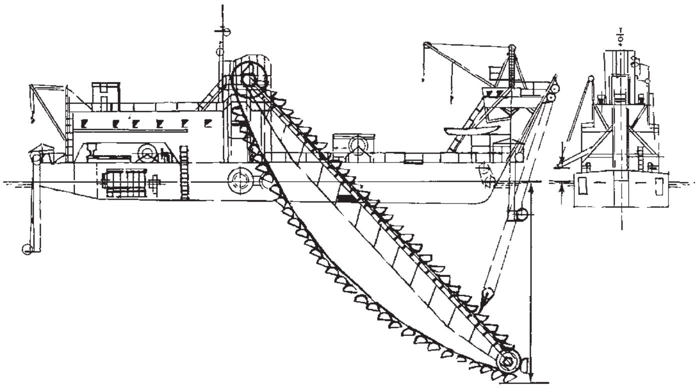
The dipper dredger is essentially a powered shovel mounted on a barge. Older versions used a rotating boom with a stick and shovel design. Later designs incorporate the whirley or rotating cab, luffing boom and a stick and bucket. These dredgers use vertical spuds to anchor them to the bottom and a digging spud at the rear of the vessel to provide resistance to the massive digging forces of the bucket.

Dipper dredgers come in all sizes but the largest of the modern versions have bucket capacities greater than 15 cubic metres. Dipper dredgers are particularly suited for dredging strong rock and highly compacted materials. They have also been used effectively in removing old subaqueous foundations from within a project area. There are limitations on dredging depths that can be dredged by dipper dredgers. Much of the work previously done by dippers is now done by large backhoes, although a few large dippers are still in use.

BUCKER-LADDER

Bucket-ladder dredgers once comprised a major part of the European dredging fleet and are in fact the direct descendants of the historic mud mills—the first dredgers. They use a series of buckets mounted on an endless chain loop. The loop is powered causing the buckets to travel in such a manner as to scoop the material from the bottom, carry the material in the upright buckets up the ladder to the top, where the buckets then rotate into an upside down position thereby discharging their contents into a chute. The material is then sent through the chute to barges or scows alongside the dredger.

Like the other mechanical dredgers, barges or scows are used to transport the dredged material to the placement or relocation sites. Bucket-ladder dredgers can be effectively



LEFT. The bucket-ladder dredger, invented by Leonardo da Vinci, is one of the oldest forms of dredger still in use.

RIGHT. Drawing of a bucket-ladder dredger.

used in a wide variety of materials up to and including soft rock. These dredgers are sometimes self-propelled to provide transport to the dredging site. They fell into disuse because of their relatively low production rates, the need for anchor lines, which often interfered with navigation traffic, and their relatively high noise levels, but they are still used for specific tasks, such as removing stiff clays and weak rock layers, trench dredging and maintenance in some ports.

Hydraulic Dredgers

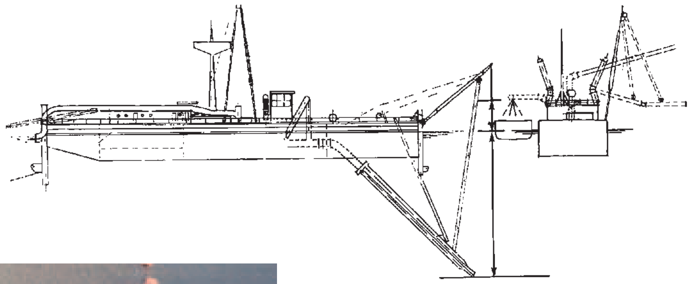
These dredgers use hydraulic centrifugal pumps to provide the excavating force, without mechanical cutters, and hydraulic transport to carry solid/water slurries from the digging site through a pipeline to the surface and thence to the discharge site. In some special cases, hydraulic dredgers pump into barges for subsequent transport to the placement site.

PLAIN SUCTION

They can dig at great depths using ladder mounted centrifugal pumps to enhance production at deeper depths and water jets to fluidise the material to be dredged. They are effective in unconsolidated materials such as sand and gravel and are used extensively in aggregate winning operations and large reclamation projects. Because of their inability to handle consolidated materials and their characteristic to produce deep excavations, they are rarely suitable or used for channel or harbour construction projects. They can be stationary or self-propelled, although self-propulsion is not used during the excavation process. In suitable materials, they have high production rates.

DUSTPAN

A rather special type of suction dredger, called the dustpan dredger, is used on river systems. They are effective where there are high bed loads or suspended solid concentrations of sand and small gravel and which, when conditions are right, form bars



ABOVE. Drawing of a suction dredger.

LEFT. One of the newest suction dredgers for deepwin sand dredging.

Dustpan dredger at work in a river.

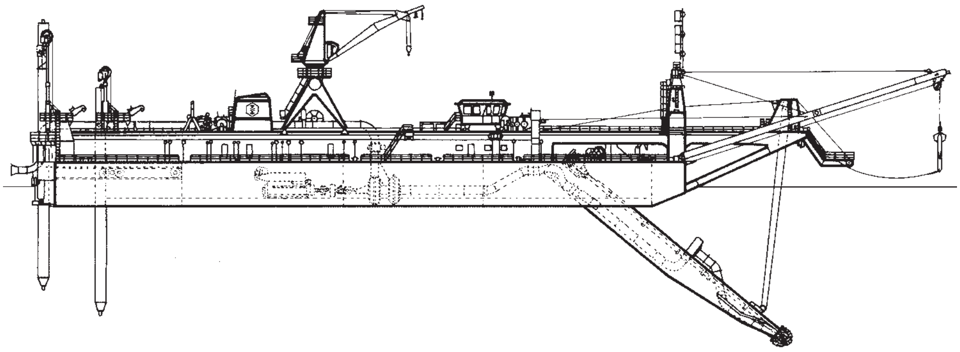
or obstructions in the navigation channels. The dustpan dredgers are capable of moving large volumes of material from localised areas using a suction head shaped much like a dustpan. The material is usually fluidised by the use of water jets along the top of the digging face of the dustpan, drawn into the suction head and up the suction pipeline, through the pump and thence through a relatively short floating discharge line. The material can be discharged into a portion of the river where high energy currents keep it in suspension and it is carried downstream and away from the constricting bar, or it can be loaded into barges or pumped ashore. Dustpan dredgers were designed for use in large river navigation systems where conditions are appropriate for their design and use.

Mechanical/Hydraulic Dredgers

Mechanical/hydraulic dredgers include the real workhorses of the dredging industry. The cutter suction or cutter-head dredger, bucket-wheel dredger and trailing suction hopper dredger are representative of mechanical/hydraulic dredgers. These dredgers are often employed on construction and maintenance projects.

ABOVE. Cutter suction dredgers (CSDs) are used for dredging rock and hard clays. This CSD is self-propelled.

RIGHT. Drawing of a cutter suction dredger.



Close up of a cutter head.

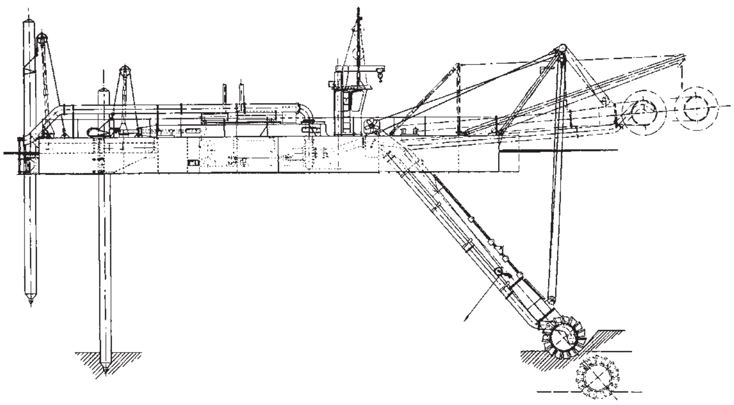
CUTTER-HEAD AND BUCKET-WHEEL DREDGERS

Both the cutter-head and bucket-wheel dredgers use rotating mechanical devices, called cutters, mounted ahead of the suction head. The cutters excavate the material into suitably sized material. This is then sucked into the suction pipe as a solid/water slurry and pumped to the surface. By use of pumps mounted on the ladder, a structural device that extends to the bottom, these dredgers can dig effectively at depths up to 36 metres.

LEFT. Bucket-wheel dredgers are mainly used in the mining industry.

BELOW. Drawing of a bucket-wheel dredger.

They are characterised by high production rates and the ability to effectively dig silts, clays, sand, gravel, cobbles, and fractured and sound rocks. The most powerful can dredge strong rocks effectively on a continuous basis. They work in a stationary mode either on spuds or anchors. Some are self-propelled to provide for transportation between work-sites. They have flexible discharge alternatives and can either discharge into barges or, as is generally the case, through discharge pipelines to the placement site. By use of booster pumps in the discharge lines, they can transport and place materials at considerable distances from the work site.



Cutter-heads rotate along the axis of the suction pipe whereas bucket-wheel dredgers rotate perpendicular to the axis of the suction pipe. The bucket-wheel is mainly found in mining applications.

TRAILING SUCTION HOPPER DREDGERS

Trailing suction hopper dredgers, or trailers, are self-propelled ships with hoppers or dredged material storage internal to the hull. They have articulated dredging pipes, or "dragarms", that extend to the sea bottom. They dredge whilst underway, travelling at low speeds.

The draghead can be either passive or active. In the case of the passive draghead, no additional power is applied at the head and material to be excavated is scoured by hydraulic currents induced at the draghead. The active draghead uses power to drive cutting teeth or high pressure water jets to excavate the material and aid in forming the solid/water slurry.

The weight of the drag system maintains the contact with the bed in both passive and active dragheads and the suction at the draghead entrains the disturbed material and

ABOVE LEFT. Artist's rendering of a trailing suction hopper dredger (TSHD) with elongated dragarm.

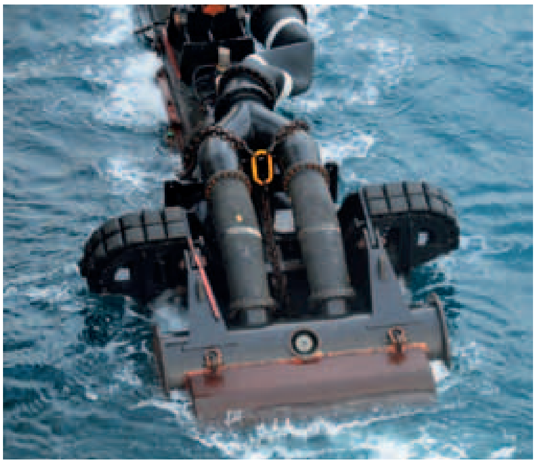
ABOVE RIGHT. TSHDs come in a wide variety of sizes and are extremely flexible. Here one of the largest next to one of the smallest.

RIGHT. Self-propelled trailers can transport sand over long distances and then place it where needed.

BELOW. A trailer placing sand by rainbowing with a double nozzle.

allows the material to be transported hydraulically as slurry. The material is hydraulically transported through suction lines, through the centrifugal pump and into the hopper, where the solids settle out and the material is retained for transport and subsequent placement. Some of the finer fractions of the dredged material will overflow with the excess water from the hopper and will fall back to the seabed again.

Trailers are quite flexible in terms of the material to be dredged, placement alternatives, and the ability to work in protected and unprotected waters. The dredged material is transported in a hopper within the vessel to a placement site remote from the work site. The material is discharged through doors or valves in the hopper bottom, or in the case of a split-hulled vessel, out of the bottom when the hull is longitudinally split; or it can be pumped from the hoppers through discharge lines to shore based placement sites with or without the use of



LEFT. On the bridge of a modern TSHD showing the dredgemaster's working area.

RIGHT. Close up of a (ripper) draghead.

booster pumps. The largest trailers now have hopper capacities in excess of 45,000 cubic metres.

Many of the larger trailers can dig effectively at depths of up to 60 metres using pumps mounted on the dragarm, and a few are designed to dredge at depths of over 150 metres. They are effective in silts, sands, clays and gravels but until recently not generally used in virgin rock dredging. They have relatively high production rates. They have the additional advantage that since they are self-propelled, they can work in congested areas with minimum disruption to ship traffic. They can also work in unprotected waters, such as entrance channels far out to sea, and under weather and sea conditions where stationary equipment is somewhat limited. The trailer is unique in the sense that it uses its self-propulsion during the excavation and transportation processes.

Hydrodynamic Dredgers

Hydrodynamic dredgers mobilise material underwater and then use the bed slopes, natural water currents and density gradients at the dredging site to move the material to a different location. They may be mechanical or hydraulic. Some of the dredgers described above can be used in a hydrodynamic mode. Those described below are specifically designed for the purpose.

WATER INJECTION DREDGERS

Although this type of process has been known for some time and utilised in special circumstances, the water injection dredger is now having some notable successes, primarily for maintenance dredging. The dredger uses water pressure to fluidise the bottom material to be removed, creating dense fluid slurry. The slurry is then transported from the excavation site by means of currents either induced by the density gradient between the slurry and that of water, or by naturally occurring currents within the dredging

ABOVE. A water injection dredger was a cost-effective way to level the seabed in Mumbai, India.

RIGHT. Artist's impression of water injection dredger at work.

FAR RIGHT. A split-hull dredger discharges its load from underneath by opening its hull.

site, such as tidal or river currents, or by the slope of the sea or river bed.

This is a relatively low-cost dredging technique whose use is limited to silts, unconsolidated clays and fine sands. The system can either be barge-mounted, and of self-propelled or stationary type, or it can be a fixed structure associated with a quay where siltation is known to occur.

PLOUGHS, BEAMS AND RAKES

This is a category of devices that are generally suspended from an A-frame, mounted on the aft end of a tug or work boat, and dragged across the sea- or riverbed. Ploughs may be specially designed beams or bottomless buckets that contain the bed material for a short period of time, whilst rakes and beams are generally of a form which merely

re-suspends the bed material. All these devices put the material to be removed either directly or indirectly into the water column as suspended sediment. Ploughs, beams and rakes have relatively very low production rates, but are inexpensive to mobilise and use. They may often be suspended from marine plant owned by the client. They may be used in conjunction with a trailer dredger (see above). Further information on hydrodynamic dredging may be found in Van Raalte and Bray (1999).

TOP. An encapsulated bucket dredger is an ecologically sound design for dredging contaminated sediments.

ABOVE. Close up of a specialised environmental disc-cutter head.

Environmental and Other Dredgers

Other types of dredgers can be utilised, some of which fit into the above categories but are not described here. These are specialised tools developed for specific purposes such as environmental clean-up, small maintenance projects, and mining and extraction operations. Of particular note are modular or portable dredgers that can be truck-hauled to the work sites. Those described above are generally the categories and types used in major construction projects and routine operation and maintenance projects.

A number of environmental clean-up dredgers have been developed in recent years to assist in the removal and confinement or treatment of highly contaminated materials. These clean-up dredgers are generally adaptations of conventional items of plant, modified so as to reduce to a minimum the amount of sediment re-suspended during dredging operations. A review of these is given in *Environmental Aspects of Dredging*, Chapter 6 on “Machines, Methods and Mitigation” (IADC/CEDA, 2008).

Equipment for Transport of Dredged Material

The transport of dredged material is an integral part of the dredging process and its mode is determined to a large extent by the type of equipment employed and the placement options available. As discussed above, hydraulic suction and cutter-head dredgers use pipelines to transport dredged materials to the placement site. For long distances to the placement areas one or more booster pumps may be required at intervals along the discharge line. Discharge lines may be floating or pontoon mounted,

or can be submerged ("sinker lines") where floating lines would interfere with navigation or shore pipelines. Often, all three types of discharge pipeline will be used on the same project.

Mechanical dredgers normally use barges or scows to transport their material. In these cases, unless the barges are self-propelled, ancillary power vessels such as tugs or tenders are used to tow or push the transport barges. These barges may be transported individually or in groups depending upon the power of the vessels and sea conditions.

The material is unloaded from the barges by being released through the bottom either through cable or hydraulically operated doors, or in the case of split-hulled barges by splitting the barge longitudinally. Sometimes the barges are unloaded using hydraulic pumps or mechanical equipment. Depending on the transport mode, costs for transport can be significant, as in the case of hydraulic pumping or barge and scow operations, or practically eliminated as in hydrodynamic methods.

TOP. Floating pipelines are used to transport dredged sand to the placement site.

ABOVE. Barges being used to transfer sediments.

Choice of Type of Dredger

The choice of dredger to be used on a specific project is determined on the basis of:

- Soil or rock conditions
- Transport options
- Dredging area configuration, including pre-dredge and post dredge water depths
- Placement requirements

For instance, rock that has not been pre-treated generally limits the types of dredgers to mechanical, or cutterhead dredgers designed specifically for rock dredging. Where the material can be dredged effectively by several types, then a more detailed consideration of operating parameters is required, such as transport options.

Trailing suction hopper dredgers are able to work efficiently in entrance channels where sea and traffic conditions make stationary plant less desirable and effective. The location of the dredged material placement areas and access to them may also play an important role in the decision on the most suitable and effective dredger type.

Transport options affect the decision-making process as illustrated in the following table:

TRANSPORT CHARACTERISTICS	PROBABLE TRANSPORT METHOD
Long distance over water	Sailing in hopper (trailing suction, hopper barge, etc.)
Long distance over land	Pumping through pipeline, or sailing to a closer location and then pumping
Short distance over water	Pumping, unless fluidisation of soil undesirable or dredging method does not allow, then barge
Short distance over land	Pumping or vehicular transport

The above table is only a general guide to the choice of transport methodology. For any project there will be a number of technically feasible alternative approaches. The final choice may need to be made on the basis of economics, ecological effects or both. All these factors require both technical and economic analysis in the decision process. For instance, the most effective dredger may not be available close to the work site and then mobilisation time and cost must be factored into the decision. To give an approximate sense of the employment of various types of dredgers, recent data (courtesy Bert Visser, www.dredgers.nl) shows the worldwide distribution of dredgers by type as;

470 trailing hopper dredgers,
262 cutter-head dredgers,
56 plain suction dredgers,
3 dustpan dredgers,
14 bucket-wheel dredgers,
8 barge unloaders,
70 backhoes/dipper dredgers,
29 bucket dredgers,
62 grab/clamshell dredgers,
71 grab hopper dredgers,
11 water injection/agitation dredgers,
1 auger dredger.

In summary, there are a variety of tools or dredgers capable of being used on a project. All of the factors mentioned above will play a part in selecting the most suitable equipment for a particular job. Ultimately, however, if the work is to be accomplished by contract, the competitive bidding process will often serve as the final decision-making mechanism.

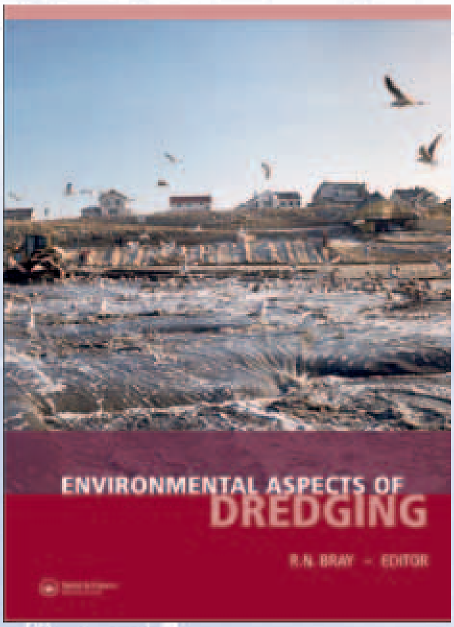
CHAPTER SEVEN

SOCIO-ECOLOGICAL ASPECTS

The most comprehensive reference on environmental matters for port and waterway development is the World Bank publication, *Environmental Considerations for Port and Harbor Development* (Davis et al, 1990) as has been mentioned earlier. It is readable and provides an extremely useful checklist as well as information on original international conventions. Much of this chapter is drawn from the World Bank publication. *Environmental Aspects of Dredging* (IADC/CEDA 2008) as well as a range of PIANC publications on specific subjects are also recommended as a relevant sources of information.

Overview of Environmental Considerations

Socio-ecological aspects are now playing an increasingly important role in port and navigation project development. The days of development strategies being based solely on economic and engineering considerations are understandably gone. Certainly, one can point out a myriad of past cases where development has occurred to the short- and long-term detriment of the environment.



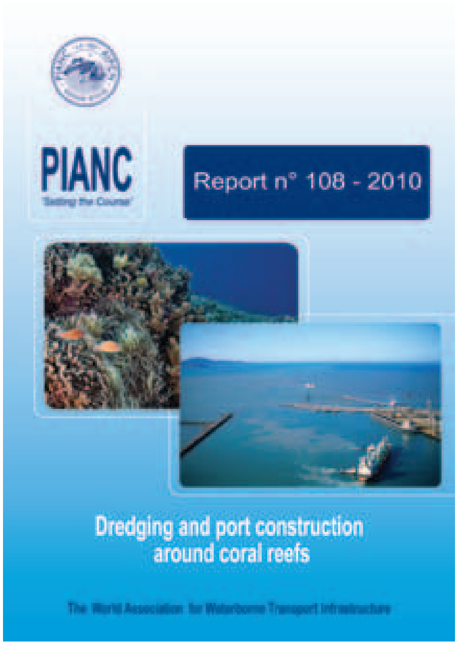
IADC/CEDA's *Environmental Aspects of Dredging* (2008) gives a complete overview of equipment, technology, scientific research and monitoring to protect the environment during dredging projects.

Industrialised countries are paying a high price to remedy the consequences of their earlier disregard of the environment. Corrective action is far more expensive than taking environmentally responsible actions from the outset of a development project. Unfortunately, dredging and dredge operators have been singled out, quite unreasonably, as the instigators of the damage to the environment when contaminated sediments have actually come from a variety of sources. Over time the dredging industry has followed scientific evidence and current public attitudes in its concern for and care of the environment (*Dredging and Port Construction Around Coral Reefs*, PIANC 2010).

TOP LEFT. A treatment facility for contaminated sediments.

BELOW. A storage depot. Facilities for the containment of sediments that cannot be treated help improve the marine environment.

LEFT. Environmental monitoring is necessary at all stages of a dredging project and in all kinds of weather conditions.



PIANC's publication *Dredging and Port Construction Around Coral Reefs.*

In spite of this, dredging projects per se often arouse emotional reactions. In fact, many large dredging projects are executed to result in long-term environmental improvement, but to achieve this some short-term negative impacts may be inevitable. The duty of the engineer is to minimise these short-term impacts. Nowadays where impacts from dredging occur, compensatory measures are implemented. Hopefully, with better information available to stakeholders, the effects of relatively small portions of dredged material that have been contaminated will be put in context and the positive remediation efforts of dredging will be recognised.

Extensive research on the treatment and placement of contaminated sediments has provided viable and environmentally acceptable solutions. However, the fact remains that because of public perception, and of past cases where dredging did result in environmental damage, strong emphasis on environmental responsibility is, and will likely continue to be, a major consideration on development projects. Recent insights on use and placement of (contaminated) dredged materials are published in *Dredging Management Practices for the Environment* (PIANC, 2009) and *Dredged Material as a Resource* (PIANC, 2009).

In this context it seems appropriate to emphasise how the unfortunate choice of vocabulary has contributed to and continues to foster the image of dredging as causing environmental damage. Terms used by dredge operators and the media have come to have pejorative connotations. "Spoil" and "sludge" and "waste" as well as the concept that dredged material is "dumped" are a few of the terms, which in the public understanding are by definition negative and environmentally objectionable. It is far better to use the term dredged material or sediments and placement, than terms that have ingrained negative meanings. In fact, most of what is dredged is environmentally clean material. The EU 2008 Waste Framework Directive acknowledges this by excluding dredged material in general from the scope of the legislation (provided of course it is non-hazardous).

The terms "placement" and "placement site" should be substituted for the traditional but negative terms of "dumping", "disposal" and "disposal site". Experience has shown that words count and public perception shapes public policies, often to a greater extent than science does. All of us in the business of dredging or port and waterway development have a responsibility to rethink, not only the essence of environmental considerations, but the perception as well.

Primary Effect Categories

Development projects have some common problems related to the environment. The primary categories can be summarised as being:

- Water-Related Effects
- Land-Related Effects
- Air-Related Effects
- Placement of Dredged Material
- Socio-cultural Effects.

Awareness and consideration of these categories must be part of the development process from the outset. Surveys of world ports by IAPH confirmed that indeed ports do consider the first four items to be major problems. In particular, these kinds of effects have a profound influence on the ecology: Any change in water/air quality, loss or alteration to habitat and the like, either at the dredging or placement site may lead to a commensurate alteration in benthos, fish life and marine mammal populations. In the following paragraphs a number of aspects of these categories will be highlighted.

WATER-RELATED EFFECTS

Effects that relate to dredging can be subdivided into the following elements:

EFFECT	CAUSED BY PROJECT	CAUSED BY PROCESS
Dispersal and settlement of resuspended sediments		•
Effects of blasting		•
Results of altered bathymetry	•	
Effects of changing shoreline configuration	•	
Loss/alteration to bottom and marine habitat	•	•
Altered water currents and groundwater flow	•	

Factors related to the placement of dredged material are more complicated and will be discussed separately.

LAND-RELATED EFFECTS

Land-related effects include:

EFFECT	CAUSED BY PROJECT	CAUSED BY PROCESS
Effects of dust and other airborne emissions	•	•
Noise of reclamation plant		•
Effects of covering land or intertidal with dredged material	•	
Runoff of saline and fresh water to local water courses	•	•

TOP: The tsunami in December 2004 destroyed many of the coral islands comprising the Maldives including Vilufushi.

ABOVE: Aerial view of the dredging works to restore Vilufushi in 2006.

AIR-RELATED EFFECTS

Dredging is unlikely to contribute directly to air-related effects except for the emissions from the prime movers of dredging equipment, which generally are negligible when compared to other factors (EuDA, 2009). Dust may be a problem in hot and dry countries. Special attention should be paid in areas where gasses are captured in the soils to be dredged, especially hydrogen sulphides. These can be dangerous during the dredging process and, if known, countermeasures could be taken.

PLACEMENT, RELOCATION OR USE

Dredged materials can be broadly divided into four categories:

1. Material derived from maintenance dredging of areas affected by sedimentation resulting from rivers or estuaries or land runoff.
2. Material derived from maintenancedredging of sand bars at the entrances to harbours, tidal inlets or channels.
3. Material derived from capital or new work dredging within a port.
4. Material derived from capital or new work dredging of channels or outer harbour areas.

Because of the nature of activities around ports, such as agriculture, industry and the treatment of wastes associated with municipalities, the material most likely to contain significant levels of contamination are those found in Category 1. Accordingly, the management of these materials is a focus of environmental concern.

Category 2 materials are far less likely to be contaminated and are often found to be suitable for beach nourishment and construction fill material or aggregates.

Category 3 materials are likely to contain significant levels of contamination in the upper levels, with the underlying materials generally being uncontaminated. Depending on the specific case, the upper levels may be subject to restricted or special placement alternatives, whilst the uncontaminated underlying material may be placed in open water, or beneficially used on land.

Category 4 materials are also likely to be contaminant free and therefore can be placed in open water, or beneficially used for such things as shoreline protection or beach nourishment.

The materials in Categories 1 and 3, which contain contaminants, are of most concern from an environmental viewpoint. They are also most likely to fall within placement restrictions stipulated in local or international agreements, statutes or conventions. The international conventions are generally limited to the placement of materials in the sea, with local restrictions. These local restrictions, if they exist at all, are either consistent with the international ocean placement conventions or established to mitigate damage from inter-tidal or upland disposal. In either case, the project sponsor must consider placement options that are environmentally sensitive and responsible.

SOCIO-CULTURAL EFFECTS

Socio-cultural effects are difficult to evaluate but are nonetheless important. Even the very best engineering, highly laudable environmental planning, and extensive economic justification can all come to nothing if socio-cultural effects are misjudged or ignored. For instance, work practices, site selection and aesthetics may run counter to socio-cultural standards and traditions. Failure to consider such factors as local tribal, cultural, ethnic, historical and religious traditions may essentially cancel any benefits from the project. Again, this is an area where the dredging process itself may have little if any impact. However, the placement of dredged material may well have a significant impact in this area and therefore should receive ample consideration.

Monitoring

It is always important to have a pre-project assessment of the characteristics of the materials to be dredged and the likely placement sites. Such characterisations permit:

- The definition of placement options;
- Quantities of materials to be suitably placed in each of the options;
- The dredging equipment to be used, not only considering the placement requirements, but also considering the transportation to the placement options and minimising sediment re-suspension and loss during dredging;
- Monitoring programmes at both dredging and placement sites;
- Mitigation measures that may be required at the dredging or placement sites.

Effective environmental monitoring of the dredging and placement sites is likely to be a requirement either under permit or consistency with international conventions. Furthermore, post-construction monitoring of placement sites, both open water and upland, are essential to determining if the mitigation measures are adequate to prevent serious environmental harm. This is particularly true where contaminated dredged materials are involved. Such monitoring is also useful in establishing a database for future work in the area where either more or less stringent controls may be appropriate. It should be noted (see Chapter 3) that monitoring periods may need to be prolonged to enable adequate data sets to be obtained.

CHAPTER EIGHT

RESEARCH, DEVELOPMENT AND TRAINING

The dredging industry is constantly striving to improve its performance, both with respect to technical and managerial efficiency, and in relation to the environment in which dredging and relocation works are carried out. To assist in these objectives, dredging companies, dredging and supporting advisory organisations, and scientific research establishments undertake a considerable amount of research and development. Staff and operative training are also carried out by the major dredging and supply companies. This work is, with few exceptions, financed by the private organisations operating in the dredging field.

Research and Development

The products of this research and development may be seen in the emergence of new and innovative working methods, environmentally friendly techniques, and the ability of the industry to predict and monitor the effects of dredging.

Some recent examples of the results of research and development are illustrated below:

The sweep dredger, the environmental auger dredger, the disc bottom dredger and the horizontal profiling grab bucket were all developed to increase dredging accuracy and to reduce the re-suspension of sediments when dredging in contaminated and non-contaminated materials.

The water injection dredger was developed to provide, in suitable locations, a quick but inexpensive method of maintenance dredging in silty areas.

The building of the large jumbo trailing suction hopper dredgers came about as a result of the need to transport large volumes of fill over long distances, because there was a scarcity of fill materials near the Far Eastern and Middle Eastern reclamation sites. The jumbo trailers also have the capacity to load materials from great depths.

Innovations such as high pressure jets on dragheads and cutterheads (Dracula system) as well as special ripper techniques recently used for dragheads enable trailer suction hopper dredgers and cutter suction dredgers to work in much harder soils than until recently had been possible.

The Netherlands Dredging Association, Vereniging voor Waterbouwers, has financed the development of turbidity assessment predictive models (TASS) for the assessment of suspended sediment generated by dredgers (Burt et al., 2000).

A number of techniques have been developed to post process the backscattered sound from acoustic current meters, thereby producing large amounts of data on the generation of plumes and the movement of suspended sediments prior to and during dredging operations (Land and Bray, 1998, Claeys et al., 2001).

Future Research Topics

Further topics for research effort are highlighted in *Environmental Aspects of Dredging* (IADC/CEDA, 2008) These are subjects that CEDA and IADC have identified as requiring to be researched. The list does not imply any particular priority, nor is it exhaustive.

A. Standard Specifications for Sampling and Testing
Methods of testing for contaminants vary greatly and there is little consistency in the procedures carried out. Analytical methods need to be standardised. Some analytical methods for the measurement of hazardous substances still need to be developed.

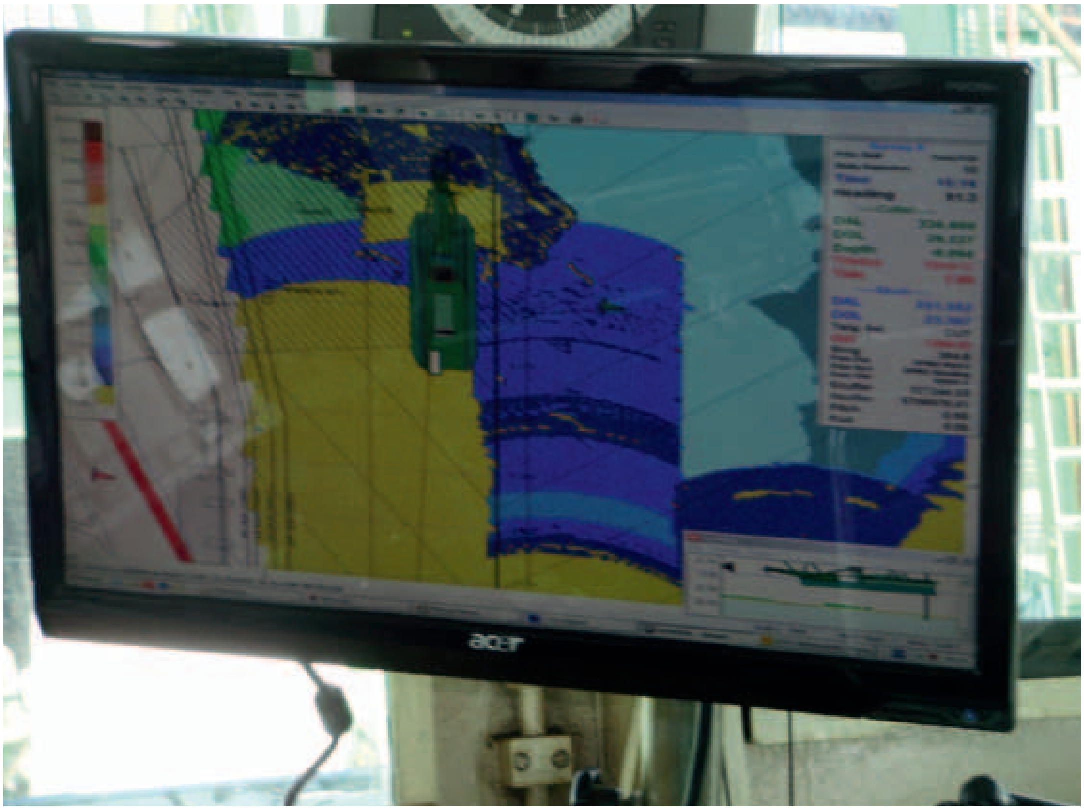
B. Placement of Capping Material on Weak Sub-aqueous Sites
Design and construction methods suitable for the placement of capping material on weak, sub-aqueous sites need to be researched and publicised. Designs for capping have been carried out and some placement techniques have been developed. They are not well known outside the industry and do not cover all types of site. Designers should be able to design capping schemes that are suitable for their environment and are constructable at reasonable cost. Currently, there is a need for more data from existing sites where capping has been carried out.

C. Environmentally sensitive dredging techniques
Chapter 6 of *Environmental Aspects of Dredging* describes a number of dredgers specially designed for working in environmentally sensitive sites. New dredgers are continually being developed, as well as new techniques for environmental mitigation. A research project is required to identify and describe mitigation measures. These measures might be specific on-site examples of mitigation techniques or more generic "greenhouse effect" measures, which are already being applied in some countries, such as reducing fuel consumption by fuel-efficiency methods, the pros and cons of electric power, use of low sulphur fuels and so on. These measures need to be promoted on a worldwide basis.

D. The Development of Cumulative Effects Analysis
An agreed, standardised method of evaluation should be adopted which puts all human (and therefore controllable) activities on the same playing field. This is a part of the so-called "cumulative effects" analysis. Research should focus attention on cumulative impact analysis; on who, ultimately, should evaluate the environmental

RIGHT. Satellite imagery is an effective means of project development though it may be costly.

BELOW. Computer modelling and databases that process relevant data quickly have helped dredgers to work with more accuracy and environmental sensitivity.



status quo of the region; on who should pay for the data collection required and how the various competing economic and environmental pressures should be balanced. Note that analysis should be on a coastal cell, watershed (catchment) wide basis.

E. The Effect of Extreme Events on Environmental Analysis

It is often the case that the degree of environmental impact from a dredging operation is less than that of an extreme natural event, such as a storm or large flood. However, these extreme events are often poorly recorded and many environmental parameters are not recorded during the extreme event because of the cost and/or difficulty. A project is required to devise means for better recording environmental parameters during extreme events and for incorporating these data into the environmental evaluation.

F. Development of inexpensive contaminant screening tools

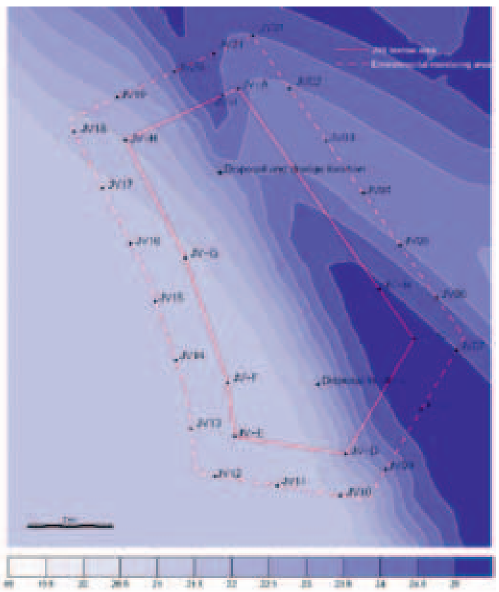
At the current time, the screening for contaminants can be a costly business, leading to the problems outlined in Research Area (a) above. To alleviate this problem, further research is required to develop inexpensive methods of screening for contaminants.

G. Assessment of chronic/sub-lethal effects of contaminated dredged material

Research is required to identify the levels of contamination in dredged material that cause chronic or sub-lethal effects on various types of organisms.

H. Assessment of the real impact of physical changes to the environment

Considerable differences exist in the biodiversity and sensitivity of ecological systems in differing latitudes and types of climate. The real impact of changes in environmental parameters needs to be investigated for the different categories. This investigation could go a long way to ensuring that regulations are applied appropriately to each particular situation, rather than indiscriminately on a worldwide basis.



Numerical models can provide realistic simulations of dredging-induced sediment plumes and help evaluate the real impacts of dredging in specific environments.

ABOVE. Training can be done on simulators such as this one, where young dredgers work on a cutter automation system.

RIGHT. Providing port authorities and others with information about the complex subject of dredging is often accomplished through seminars and site visits.

Training

Training is one of the essential ingredients needed to produce a healthy, safe, efficient and environmentally sensitive dredging industry. Apart from the obvious commercial advantages of having well trained operatives in control of dredging plant and well trained staff managing the deployment of this plant, there are other less obvious considerations. Much has been written about the environmental effects of dredging activities and there are many publications covering this area. Most of these focus on the equipment itself. But it is the skill of the operator using the plant that often is the major factor in determining whether the dredging operations will have a high or low environmental effect on its surroundings.

The IADC website www.iadc-dredging.com provides an overview of dredging related programmes at universities and colleges around the world. A few colleges and universities have post-graduate and master programmes specifically aimed at dredging and maritime construction, namely:

- The Delft University of Technology, whose Engineering Faculty with master and post graduate programmes for Hydraulic Engineering, Dredging Engineering and Offshore Engineering;
- Texas A&M University, which includes the Center for Dredging Studies;
- The UNESCO-IHE Institute for Water Education with a MSc in Water Science and Engineering;

Non-commercial education and training in matters related to dredging is provided by a few organisations, such as:

- IADC's Seminar on Dredging and Reclamation. This seminar is presented biannually with UNESCO-IHE in Delft, The Netherlands and at another location such as Singapore in cooperation with the National University of Singapore or Buenos Aires or Dubai (UAE);
- IADC/CEDA Seminar on the Environmental Aspects of Dredging provided with the post-academic education institute of Delft University of Technology as well as on request (IMO, CEFAS UK and others);
- USACE Various manuals and guidance notes issued by Waterways Experiment Station at Vicksburg and educational website http://education.usace.army.mil

Dredging contractors also provide many in-house courses and programmes such as the VOUB programme that has been developed by the Netherlands Dredging Association (Vereniging voor Waterbouwers). Finally, a commercial institution, the Training Institute for Dredging (www.dredgetraining.com), regularly organises short courses on dredging and related subjects. Tailor-made courses can be designed on request.

CHAPTER NINE

INTERNATIONAL, REGIONAL AND NATIONAL AGENCIES

Dredging projects in developing nations are often dependent on the availability of funds from third parties in the form of lending agencies. A number of possibilities exist, including global, regional, and national lending agencies. Financial support from these agencies is often dependent on adherence to the international and regional conventions that govern the placement of dredged materials at sea.

Global Lending Agencies

The largest and most widely active of the lending agencies is the World Bank, sometimes referred to as the World Bank Group. It consists of a number of affiliates, namely:

- International Bank for Reconstruction and Development (IBRD)
- International Development Association (IDA)
- International Finance Corporation (IFC)
- Multilateral Investment Guarantee Agency (MIGA)
- International Centre for Settlement of Investment Disputes (ICSID)

The common objective of these institutions is to help raise the standard of living in developing countries by channelling financial resources from developed countries to the developing world.

IBRD is owned by the governments of 185 countries and makes loans towards developing countries at more advanced stages of economic and social growth. Loans generally have a grace period of five years and are repayable over fifteen years or less and must be guaranteed by the government concerned. The interest rate is calculated in accordance with a guideline related to its cost of borrowing. The Banks decision to lend must be based on economic considerations alone, with due regard to the prospects of repayment. Typically, concerning port and waterway development, the loan would be made to the port authority, the port itself or to some parastatal agency responsible for waterways.

IDA has the same objectives as the IBRD but provides assistance concentrated on the very poorest developing countries, and on terms that would bear less heavily on their balance of payments. About 80 countries are currently eligible. The terms of IDA credits, which are international, regional, and national agencies made only to governments, are ten year grace periods, thirty-five or forty years maturity and no interest. For port and

waterway development, the loan would probably be on-lent to the port authority, port or waterway agency at interest rates which reflect the cost of borrowing and with a maturity based on the agency's financial capabilities.

Raising the standard of living in developing countries is the common objective of international lending agencies. Modern ports that promote marine transport, trade and tourism are essential to prosperity.

IFC assists the economic development of developing countries by promoting growth in the private sector of their economies and by helping to mobilise domestic and foreign capital for this purpose. IFC has, for instance, through equity contribution and other means promoted the development of a number of marine terminals and port facilities mainly associated with industrial activities. Some of these projects have included major dredging works.

MIGA was established to encourage equity investment and other direct investment to developing countries. MIGA offers investors guarantees against non-commercial risks; advises governments on policy and programmes to encourage foreign investments; and sponsors a dialogue between the international business community and host governments on investment issues. It is worth noting here that commercial banks and other private financial bodies have become quite interested in port facilities and operations as potential areas for investment. Worldwide most ports are profitable and are also foreign exchange earners and thus are attractive to commercial investors.

The World Bank's current focus is on the achievement of the Millennium Development Goals (MDGs) in which goals 7 (Insurance of environmental sustainability) and 8 (Develop a global partnership for development) are specifically relevant for dredging.

ABOVE. Cost-efficient projects are to everyone's benefit. To that end once a dredging project is underway, work often continues day and night, 24/7.

RIGHT. On the bridge at night.

Regional Lending Agencies

Paralleling the World Bank, a number of regional development agencies have been instituted to serve specific areas of the world.

These are:
- European Bank for Reconstruction and Development
- African Development Bank
- Inter-American Development Bank
- Asian Development Bank.

In addition, there are other multilateral financial institutions (MFIs), such as:
- European Commission (EC) and European Investment Bank (EIB)
- International Fund for Agricultural Development (IFAD)
- Islamic Development Bank (IDB)
- Nordic Development Fund (NDF) and Nordic Investment Bank (NIB)
- OPEC Fund for International Development (OPEC Fund).

And sub-regional banks, such as:

- Corporacion Andina de Fomento (CAF)
- Caribbean Development Bank (CDB)
- Central American Bank for Economic Integration (CABEI)
- East African Development Bank (EADB)
- West African Development Bank (BOAD).

These banks provide funds for development in their regions in much the same manner as the World Bank.

EUROPEAN NEIGHBOURHOOD AND PARTNERSHIP INSTRUMENT

In 1991 the EC launched the "Technical Aid to the Commonwealth of Independent States" (TACIS) Programme to provide grant-financed technical assistance to 12 countries of Eastern Europe and Central Asia (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan). TACIS is now subsumed in the EuropeAid programme. From the 2007-2013 EU Financial Perspective, the TACIS Programme has been replaced for the countries of the European Neighbourhood Policy and Russia by the European Neighbourhood and Partnership Instrument.

ASIA PRO ECO II

The Asia Pro Eco Programme was launched in 2002 as an initiative by the European Union (EU) to strengthen the environmental dialogue between Europe and Asia. This five-year programme aimed to provide support to European and Asian organisations to enable them to share strategies, advanced technologies and know-how in addressing Asian environmental issues. Asia Pro Eco II is a programme which builds upon the environmental achievements of the Asia Pro Eco I and the Asia Urbs I+II programmes. Asia Pro Eco II funds EU-Asia partnership projects specifically in the field of the Urban-Environment.

National Lending/Development Agencies

On a smaller scale, most of the industrialised nations have set up government departments to handle the provision of bilateral aid to a number of targeted countries or regions. The focus of this development assistance is normally affected by historical relationships or current trading patterns. For instance, the British, Dutch and French aid programmes often, but not exclusively, aimed at those countries which were once their colonies. This bias has now shifted to reflect the changing trading arrangements and socio-political aspects of the modern world. In cases of emergencies, such as flooding in Bangladesh, or the tsunami in Southeast Asia, many nations cooperated to bring aid to the hard-hit regions.

CHAPTER TEN

REGULATORY BODIES

International and Regional Conventions

THE LONDON CONVENTION AND OSPAR

The oceans have long been considered to have a limitless capacity to receive and absorb all manner of wastes. Beginning in the 1950s, various scientists began to warn that this limitless capacity was running out and that the very survival of the marine environment was in doubt.

Many environmental groups began to demand that all waste disposal in the marine environment cease. The initial focus was on disposal of waste chemicals and nuclear wastes or incineration at seas of waste organo-halogen compounds. Subsequently, the disposal of sewage sludges and the large volumes of dredging materials, particularly those from heavily industrialised urban centres led to demands that these materials also not be permitted to be placed in the oceans. Such demands were not limited to the oceans; for example, in the early 1970s both the United States and Canada limited the relocation of dredged material from the Great Lakes to confined shoreline or upland facilities with very little material being permitted to open water.

Beginning with the Oslo Convention of 1974 and the Paris Convention of 1978, the European nations sought to limit the input of contaminants to the adjacent marine waters. The conventions addressed international waters. It was accepted that the placement of dredged materials could occur provided the materials contained only trace quantities of contaminants. Materials that are primarily sand, gravel, or rock, from areas of strong currents and are therefore not likely to contain significant concentrations of fine-grained contaminated sediments and which are intended for beach nourishment or other forms of shoreline protection should not have to be tested. (Note: Fine-grained sediments, such as silts and clays, have a tendency to sorb or bind contaminants thereby becoming contaminated by these bound contaminants, whereas sands do not have such characteristics.)

The intergovernmental convention of the "dumping" of wastes at sea, commonly called the London Convention of 1972 (LC72), adopted the general philosophy and has many of the same articles as the Oslo Convention and applies to all international waters. The LC72 contains a series of Annexes listing a large number of chemicals and chemical compounds which are deemed hazardous or potentially hazardous and therefore worthy of regulation. As with the earlier conventions, LC72 was designed primarily to regulate the dumping of chemical or industrial wastes in the marine environment.

The regulation of dredged materials and their placement in the open ocean have revolved around the following terms:

- trace contaminants,
- significant amounts,
- rapidly rendered harmless,
- toxic, persistent, and
- bio-accumulative.

The question then arises as to what concentrations of such compounds can be considered trace or in such a form as to be rapidly rendered harmless. The latter term arose from the chemical reactions that occur when various metal-contaminated liquids are inter-mixed with seawater and the elevated pH and salinity rapidly create insoluble metal compounds, which are then not available to the biota.

The LC72 guidelines on dredged material disposal recommend:

- representative sampling,
- measuring the general characteristics,
- measuring the priority contaminants, and
- biological testing, if necessary,

to show that the material can be discharged so as not to cause acute chronic effects or bio-accumulation in sensitive marine organisms typical of the disposal site.

More recently the Convention issued a Waste Assessment Framework that sets out the basic practical, though not necessarily detailed, considerations required for determining the conditions under which materials might or might not be deposited in the sea. There is a part of this framework devoted to dredged material, in the form of a generic guideline for decision-makers in the field of management of dredged material The dredging industry prefers to call this the Dredged Material Assessment Framework (DMAF) as the industry does not consider dredged material to be a waste (see Figure 1. on page 23).

The Convention has also adopted the precautionary principle that states that even though there may not be scientific evidence of environmental damage, the likelihood of such damage should be viewed with caution and thereby avoided. Further, the convention has also confirmed the “polluter pays” concept, wherein those who actually created the contamination problem should be responsible for the costs of remediation.

Compliance with the London Convention of 1972 and other pertinent international agreements are mandatory for those projects that wish to be financed by international lending organisations such as the World Bank and the Regional and Sub- Regional Banks.

The United Nations Environmental Programme (UNEP) is one of the agencies that supports sustainable development.

Further information on the London Convention and regional conventions that apply to dredged material may be found in *Environmental Aspects of Dredging*, “Annex A” (IADC/CEDA, 2008).

UNITED NATIONS ENVIRONMENTAL PROGRAMME (UNEP)

In the United Nations Environmental Programme (UNEP) it has been recognised that almost 50% of the world’s coasts are threatened by development-related activities. The health, well-being and, in some cases, the very survival of coastal populations (about 1 billion people are living in coastal urban centres) depends upon the health and well-being of coastal systems such as estuaries and wetlands.

With this in mind, members of UNEP have set up a Global Programme of Action (GPA) for the protection of the Marine Environment from Land-based Activities (1995). The GPA is designed to be a source of conceptual and practical guidance to be drawn upon by national and/or regional authorities for devising and implementing sustained action to prevent, reduce, control and/or eliminate marine degradation from land-based activities.

For further information see www.gpa.unep.org.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO (International Organization for Standardization) is the world’s largest developer of standards. It is a network of national standards institutes from 163 countries working in partnership with international organisations, governments, industry, business and consumer representatives. It is a bridge between the public and private sectors.

THE EUROPEAN COMMISSION

Regional organisations, such as the European Commission, may issue directives that have to be complied with by the countries represented by the Commission. Some of these directives affect dredging. For instance, the following directives impact directly on dredging and placement activities:

- The Water Framework Directive
- The Waste Framework Directive
- The Habitats Directive and Birds Directive.

NATIONAL AGENCIES

A characteristic of the international agreements, described above, is that signatories to them must identify suitable government departments to implement the recommendations and protocols of the conventions. These departments must also develop compatible environmental protection in their national legislation. Thus, for example, a country's Environmental Protection Department might be tasked with developing the framework for assessing the management of dredged material in accordance with the Dredged Material Assessment Framework.

Further guidance on this subject may be found in Environmental Aspects of Dredging, Annex A (IADC/CEDA, 2008), but it should be noted that country-specific regulations and permitting procedures are updated and change frequently. Therefore, entities considering dredging and marine construction projects are well advised to consult the national, regional and local authorities to ensure that they meet all requirements before embarking on the project.

APPENDICES

APPENDIX A

INTERNATIONAL AND NATIONAL ORGANISATIONS

Pertinent International and National Organisations

American Association of Port Authorities (AAPA), 1010 Duke Street, Alexandria, VA 22314, USA. Website: www.aapa-ports.org

American Society of Civil Engineers (ASCE) Headquarters, 1801 Alexander Bell Drive, Reston, VA 20191, USA. Website: www.asce.org

Center for Dredging Studies, Civil Engineering Department, Texas A&M University, College Station, TX 77843-3136, USA. Website: http://oceaneng.civil.tamu.edu

Central Dredging Association (CEDA), PO Box 488, 2601 AL Delft, The Netherlands. Website: www.dredging.org

CIP-OAS, The Inter-American Committee on Ports – Organization of American States, 1889 "F" St N.W., Washington, D.C. 20006, USA, Tel. (202)458 3871, Fax. (202)458 3517, cip@oas.org. Websites: http://www.oas.org/CIP/index.html or http://www.oas.org/CIP/english/

Delft University of Technology, PO Box 5, 2600 AA Delft, The Netherlands. Website: www.tudelft.nl

Eastern Dredging Association (EADA), Secretary General, c/o Port Klang Authority, Mail Bag Service 202, 42009 Port Klang, Malaysia.

Environmental Laboratory, Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, USA. Website: www.erdc.usace.army.mil

Equator Principles (http://www.equator-principles.com),

Fédération Internationale des Ingénieurs-Conseils (FIDIC), World Trade Center II, PO Box 311, CH-1215 Geneva 15, Switzerland. Website: www.fidic.org

Institution of Civil Engineers (ICE), 1 Great George Street, London SW1P 3AA, UK. Website: www.ice.org.uk

International Association of Dredging Companies (IADC), Secretariat General, PO Box 80521, 2508 GM, The Hague, The Netherlands. Website: www.iadc-dredging.com

International Association of Ports and Harbors (IAPH), 7th Floor, South Tower New Pier Takeshiba, 1-16-1 Kaigan Minato-ku, Tokyo 105-0022, Japan. Website: www.iaphworldports.org

International Maritime Organization, Office of the London Convention of 1972, 4 Albert Embankment, London SE1 7SR, UK. Website: www.londonprotocol.imo.org.

Training Institute for Dredging (TID), PO Box 8, 2960 AA Kinderdijk, The Netherlands. Website: www.dredgetraining.com

UNESCO-IHE Institute for Water Education, PO Box 3015, 2601 Delft, The Netherlands. Website: www.unesco–ihe.org

UNCTAD, United Nations Conference on Trade and Development, Palais des Nations, 8-14, Avenue de la Paix, 1211 Geneva 10, Switzerland. Website: www.unctad.org

UNESCAP, (United Nations Economic & Social Commission, Asia and Pacific), Transport and Communications Division, United Nations Building, Rajadamnern Noie Avenue, Bangkok 10200, Thailand. Website: www.unescap.org

UNIDO, United Nations Industrial Development Organization, PO Box 300, A-1400 Vienna, Austria. Website: www.unido.org

US Army Corps of Engineers, Headquarters, Director of Civil Works, 441 G Street, NW, Washington, DC, 20314, USA. Website: www.usace.army.mil

Western Dredging Association (WEDA), PO Box 5797, Vancouver, WA 98668, USA. Website: www.westerndredging.org

World Association for Waterborne Transport Infrastructure (PIANC), Graaf de Ferraris Building, 11th Floor, Boulevard du Roi Albert II, 20-Box 3, B-1000 Brussels, Belgium. Website: www.pianc-aipcn.org

Development Banks

Inter-American Development Bank, 1300 New York Avenue NW, Washington, DC 20577, USA. Website: www.iadb.org

Caribbean Development Bank, PO Box 408, Wildey, St. Michaels, Barbados, West Indies. Website: www.caribank.org

Asian Development Bank, PO Box 789, 0980 Manila, Philippines. Website: www.ADB.org

African Development Bank, Rue Joseph Anoma, 01 BP 1387 Abidjan 01, Ivory Coast. Website: www.afdb.org

European Bank for Reconstruction and Development (EBRD), One Exchange Square, London EC2A 2JN, UK. Website: www.ebrd.com

European Development Fund of the EC, Rue de Genève 12, B-1140 Brussels, Belgium. Website: www.europa.eu.int/comm/development

European Investment Bank, 100 Boulevard. Konrad Adenauer, L-2950 Luxembourg. Website: www.eib.org

The World Bank, 1818 H Street NW, Washington, DC 20433, USA. Website: www.worldbank.org

Acronyms

AAPA	American Association for Ports and Harbors (USA)
ASCE	American Society of Civil Engineers (USA)
EC	European Community
FIDIC	Fédération Internationale de Ingénieurs-Conseils
IADC	International Association of Dredging Companies
IAPH	International Association of Ports and Harbors
ICC	International Chamber of Commerce
ICE	Institution of Civil Engineers (UK)
IMO	International Maritime Organization
ISO	International Organisation for Standardisation
LC72	London Convention of 1972 (formerly London Dumping Convention)
OSPAR	The Oslo and Paris Commission
PIANC	World Association for Waterborne Transport Infrastructure
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme

APPENDIX B

RECOMMENDED LIST OF PUBLICATIONS ON DREDGING AND PORT DEVELOPMENT

Books, Reports and Monographs

AAPA (1970) Port Maintenance. American Association of Port Authorities, Washington, DC, USA.

AAPA (1973) Standing Committee IV, Construction and Maintenance, Port Planning, Design and Construction: A Manual. American Association of Port Authorities, Washington, DC, USA.

Aarninkhof, S. (2008)"The Day After We Stop Dredging: A World Without Sediment Plumes". Terra et Aqua, nr 110, March.

Aarninkhof, S. and Luijendijk, A. (2010) "Safe Disposal of Dredged Material in a Sensitive Environment Based on Innovative Plume Predictions". Terra et Aqua nr 119, June.

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The International Association of Dredging Companies and the International Association of Ports and Harbors

have joined together to provide an introduction to the complex subject of dredging. Dredging is essential to the construction and maintenance of navigation and port projects, to the development of offshore energy resources, and in the remediation of contaminated industrial sites. Whilst many publications exist aimed at those who deal with dredging as a speciality, this book is designed especially for managers, planners, decision-makers and stakeholders. Originally published in 1983 with developing nations in mind, it is now in its sixth edition and has gained a wide audience encompassing all who wish to gain a better understanding of the dredging process and of feasible and sustainable navigation projects.

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