Waste Assessment Guidelines Training Set Extension for the Application of Low-technology Techniques for Assessing Dredged Material

Executive Summary

In 1972, the London Convention (LC) was adopted to protect the world's oceans. It was updated in 1996 by the London Protocol (LP) that came into force in March 2006. In recognising the need for guidance in implementing Annex 2 of the LP and to assist national governments with the assessment of wastes or other material that may be considered for dumping the Contracting Parties developed the Waste Assessment Guidelines (WAG). To make the WAG more accessible the Contracting Parties further developed a WAG Training Set (WAG TS) which comprised of a set of instruction materials intended for use by national authorities responsible for regulating the ocean dumping of wastes.

In conducting regional workshops a need was identified for a low-technology version of the WAG TS to focus on assessing dredging material for those countries where regulations are absent or at an early stage of development and where access to technical equipment and knowledge may be limited

Therefore this WAG TS Extension for the application of low-technology techniques for assessing dredged material has been developed. It aims to assist individuals or bodies in reviewing operations and provide the tools from a simple starting point to incrementally build an assessment, management and permitting system for dredged material to be considered for disposal to sea. Accordingly, the training set provides information on low-cost sampling, testing, information gathering and documenting, low-cost monitoring and feedback surveys to improve decision making. The WAG TS Extension is based on the WAG TS and the Specific Guidelines for Assessment of Dredged Material. It is presented as a stand-alone document but follows the same format and approach as the WAG TS but it is more directing in the sense that low-tech approaches are identified and explained to enable the user to make an informed choice. Where it has been determined that there are no low-tech alternatives the WAG text has been amended to make it more accessible for those operating in a low-tech environment

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Glossary and Acronyms

Action Levels	Establish decision rules to identify dredged materials that may be disposed because the risk for adverse effects is low and acceptable, those that may not be disposed without management controls because the risks for adverse effects would be considered too high, or to identify cases where additional information may be required to make a sound judgement about the potential for the dredged material to cause adverse effects.
Action List	Can consist of chemicals of interest, biological responses of concern, or other characteristics that can provide insight into the potential for dredged material to cause adverse effects in the marine environment.
anoxic	Without oxygen.
anthropogenic	Originating from the activity of humans.
background	The conditions observable in the vicinity of the site that are due to natural conditions, i.e. not due to anthropogenic activities.
Barcelona Convention	Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.
benthic, benthos	“Benthic" refers to the bottom of the ocean; the sediment or other substrate and the plants and animals that live there; "benthos" are the benthic biota.
bioaccumulation	tendency for environmental contaminants to accumulate in plant and animal tissues.
bioassay	Tests in which organisms are exposed to xenobiotic chemicals (chemicals not normally produced by, or expected to be, in organisms) to determine their effects or toxicity.
biota	living organisms
CEDA	Central Dredging Association, one of the three autonomous sister organizations, along with WEDA and EADA, that constitute WODA.
CEFAS	In the United Kingdom, Centre for Environment, Fisheries and Aquaculture Science.
clay	Sedimentary mineral particles 0. 2 to 2.0 μm in size, usually with a negative charge (anion); the size and charge have profound implications for sediment chemistry and other physical interactions.
contamination	The presence of a minor and unwanted constituent in another material, metal, chemical or mixture, often at the trace level.
EPA	In the United States of America, the Environmental Protection Agency.
fractions	Marine sediments are composed of mineral particles ranging in size from clay to sand and gravel, together with the biota, biogenic and chemical components and interstitial fluids; the chemical and organic components vary with grain size, the different ranges of which are call fractions.
GPA	The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities adopted in 1995.
HELCOM	Helsinki Commission, the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area," more usually known as the Helsinki Convention.
IMO	International Maritime Organization.
London Convention (LC)	Outside of this training, the “London Convention” sometimes refers to both the London Convention 1972 and the London Protocol 1996
London Protocol (LP)	The 1996 Protocol to the London Convention 1972
MARPOL	The International Convention for the Prevention of Pollution of

	Ships (MARPOL 73/78), adopted in 1973 and subsequently modified by 1978 Protocol.
Nairobi Convention	Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region.
organochlorines (OC)	A group of chemicals which include pesticides such as DDT
organotins	Organic compounds that include tin and are common in marine antifouling paints used on ship hulls; common mixtures include monobutyltin, dibutyltin, and tributyltin.
OSPAR	The Convention on Protection of the Marine Environment of the North-east Atlantic.
polycyclic aromatic hydrocarbons (PAHs)	A family of compounds with more than one benzene ring, for example, benzo(a)pyrene, many of which are carcinogenic.
particle size	Sediment and soil are defined, in part, by the relative proportions of sand, silt, and clay (see "fractions").
Party (or Parties)	Parties to the Convention or Contracting Parties, i.e., countries that have agreed to be bound by the London Convention or the London Protocol.
permitting authority	The government agency that has the legal authority to permit or refuse ocean dumping and to prosecute violations of dumping regulations. In some countries, it could refer to an individual who has this authority. In practice, however, it means the staff of those agencies.
persistent	Chemical compounds that resist degradation.
PIANC	The International Navigation Association.
polychlorinated biphenyl (PCB)	A family of very stable organic compounds based on a pair of benzene rings with varying number and placement of chlorine atoms; they are extremely persistent in the environment and this, plus their high affinity for fats, gives them high bioaccumulation factors.
practicable	Idea that a project, or scheme that can be realized, with the available resources and within the given constraints of cost and time.
precautionary principle	appropriate preventative measures are taken when there is reason to believe that environmental damage may occur even when there is no conclusive evidence to provide a causal relation between inputs and their effects (taken from Article 3.1 of the LP)
sand	Mineral particles > 63 µm in size.
silt	Sedimentary mineral > 2.0 µm to 50 µm or 63 µm in size; particles between 50µm and 63µm are often called “coarse silt”, although in some situations all particles > 50 µm are considered sand.
Zone of Siting Feasibility (ZSF)	Area where dredged material can be reasonably transported and disposed taking into account economic and operational feasibility
TBT	Tributyltin, an organic form of tin (see organotin above) used as an antifouling paint on ship hulls.
total organic carbon (TOC)	A standard measure of organic material in sediments that strongly influences the amount of contaminants (especially organic compounds) that the sediment can contain.
toxic	Has lethal or debilitating effects when ingested or contacted externally, such as exposure to gill membranes during respiration or to skin.
UNCLOS	The United Nations Convention on the Law of the Sea lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources.

WAG	Guidelines For The Assessment Of Wastes Or Other Matter That May Be Considered For Dumping (referred to as "Waste Assessment Guidance" in some documents). More recently, a set of waste assessment guidelines specific to certain categories of waste has been developed. Hence, the original WAG is sometimes referred to as the "generic WAG."
WODA	World Organisation of Dredging Associations. A non-profit professional organisation, dedicated to the exchange of knowledge and information related to dredging, navigation, marine engineering and construction. WODA is composed of the Western Dredging Association (WEDA) serving the Americas, the Central Dredging Association (CEDA) serving Europe, Africa, and the Middle East, and the Eastern Dredging Association (EADA) serving the Asian and Pacific region. The three sister Associations that form WODA share the mission of WODA and operate autonomously. Members of CEDA, EADA and WEDA include designers, builders and suppliers of dredging equipment, dredging companies, port authorities, shipping and business interests, academics, representatives of all levels of government, and other stakeholders. *www.woda.org*

1 Part 1: Introduction

1.1 Waste Assessment Guidance

In 1972, the London Convention (LC) was adopted to protect the world's oceans. It was updated in 1996 by the London Protocol (LP) that came into force in March 2006.

Annex II of the Protocol outlines eight steps for the assessment of wastes or other matter that may be considered for dumping:

1. Waste prevention audit;
2. Consideration of waste management options;
3. Characterisation of the chemical, physical, and biological properties of the waste;
4. Comparison to an action list;
5. Dump-site selection;
6. Assessment of potential effects of the dumping;
7. Compliance and field monitoring; and
8. Permit and permit conditions.

To apply Annex II, 'Guidelines for the Assessment of Wastes or Other Matter that May be Considered for Dumping' or in short 'Waste Assessment Guidance' (WAG) were developed by the contracting parties to the LC/LP to be used by national authorities and assist individuals or bodies who may be regulators, potential regulators or port operators in reviewing operations and provide the tools from a simple starting point to incrementally build an assessment, management and permitting system for dredged material to be considered for dumping in the ocean. The WAG contains procedures to guide authorities in evaluating applications for dumping of wastes. However, it is recognised that some of the approaches detailed in the WAG require technical equipment and knowledge that may not be available or affordable by those countries in the early stages of considering waste management and dumping in the ocean options.

The WAG and a set of waste-specific guidelines that have been prepared are available on-line in English, Spanish and French at:
http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx

1.2 Waste Assessment Guidance Training Set

The contracting parties to the LC also developed training material in the form of the 'Waste Assessment Guidance Training Set' or 'WAG Training Set' to guide implementation of the LP. The WAG Training Set (WAG TS) includes a Tutorial Booklet, an Instructor's Manual, and electronic presentation slides. It demonstrates the general concepts of the WAG and addresses national administrations responsible for waste management. It explains key components of the WAG and offers access to experience of Contracting Parties during the last 30+ years in regulating ocean dumping.

This document presents an extension to the WAG TS applying non- and/or low-technology techniques for the assessment of dredged material. This WAG TS Extension is an important approach to allow countries to adopt a precautionary approach to the management of dredged material. It can be used as a temporary measure, in the event that they have not yet developed sufficient capability to allow them to follow the full approach of the Guidelines. A precautionary approach is a fundamental part of any waste management policy and practices; appropriate preventive measures are taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm, even when there is no conclusive evidence to prove a causal relationship between inputs and their effects.

The WAG TS is available on-line at;
http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx

The WAG TS Extension that we have developed can be summarised as:

1. guidance on the WAG approach and its application in a low technology environment;
2. information on low-cost sampling, testing, information gathering and documentation consistent with the WAG approach, to allow characterisation of the dredged material and selection of suitable dump-sites;
3. guidance on simple and low-cost monitoring of dumping activities, and feedback surveys to improve decision making;
4. case study examples; and
5. following the same format and structure as the WAG.

The basic approach and structure of the low-tech WAG TS Extension is the same as for the original WAG, and follows the Dredged Material WAG (Figure 1). The starting point for this low-tech extension to the WAG was the original version and a determination on whether the information and approaches described in the text had low-tech alternatives. Where low-tech alternatives have been identified these are described in detail. As this is intended to be a stand a lone document it follows the same format as the WAG and where it has been determined that there are no low-tech alternatives the WAG text has been amended to make it more accessible for those operating in a low-tech environment.

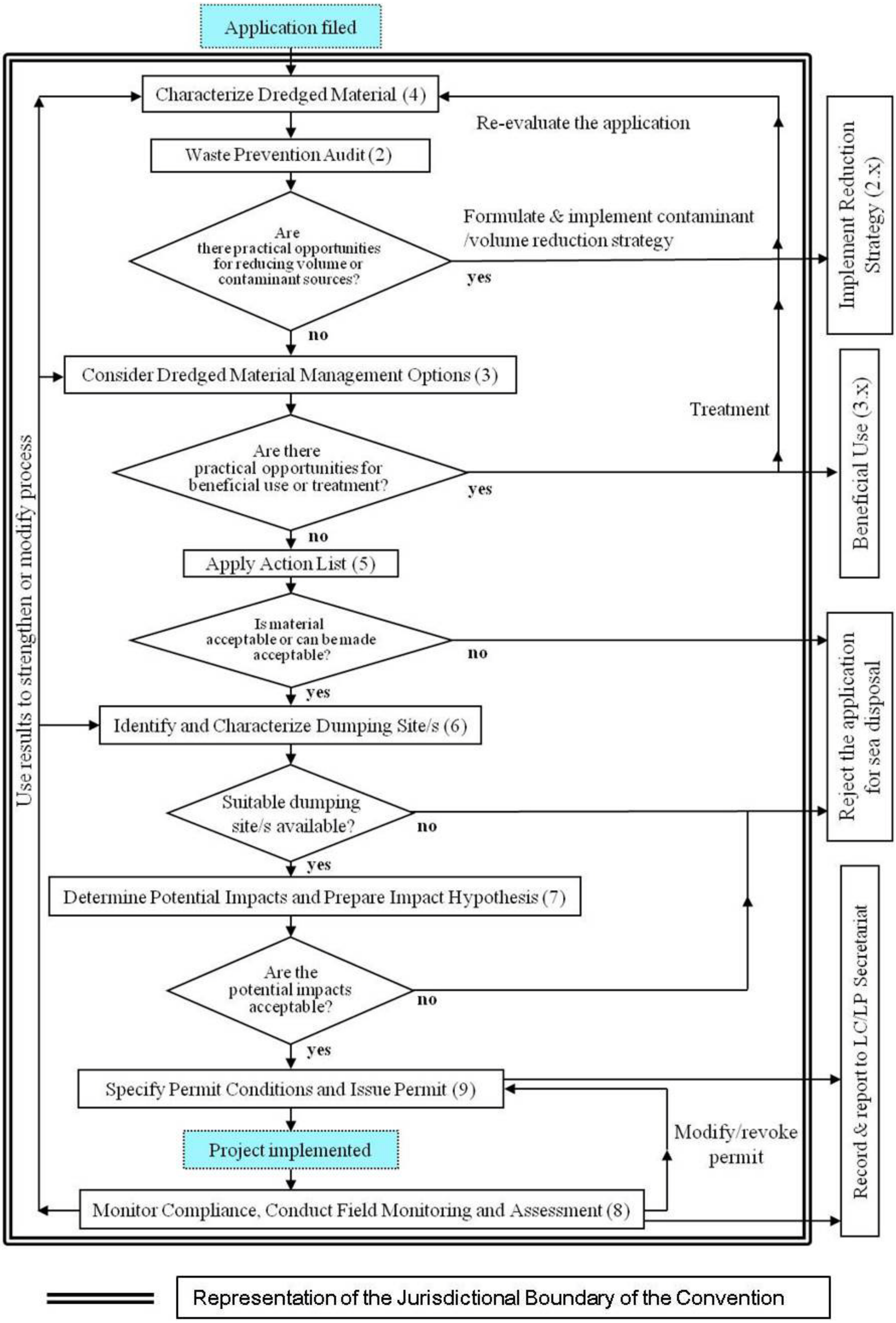

Figure 1. The dredged material assessment framework (revised figure from the Specific Guidelines for Assessment of Dredged Material) – the low-tech WAG TS Extension follows the same rationale.

1.3 Target Audience

This low-tech WAG TS Extension to targeted at those countries where regulations are at present absent or at an early stage of development and where technical equipment and knowledge may be lacking or too expensive to realistically set up from scratch without a long lead in time. They are intended to assist individuals or bodies who may be regulators, potential regulators or port operators in reviewing operations and provide the tools from a simple starting point to incrementally build an assessment, management and permitting system for dredged material to be considered for dumping in the ocean.

In the most part it is anticipated that the target audience will be countries that are not yet signatories to the London Convention and Protocol but that have aspirations to better manage dumping of dredged materials at sea, and who may in the future consider signing up to the London Protocol. The intention of the low-tech extension of the WAG is therefore to get countries to the stage that they can start to develop and adopt the steps set out in the full WAG.

1.4 Terminology

In line with the terminology used in the London Convention and Protocol WAG and WAG TS, dredged material is one of the 'wastes or other matter' that is permitted to be dumped at sea. The term waste is used here in line with the WAG and WAG TS, however, organisations dealing with dredged material (WODA, CEDA, PIANC, EUDA) consider that it is a resource and therefore do not consider it as a waste. As the term dumping is often associated with waste the term disposal is also used in reference to dredged material in these guidelines.

2. Part 2: London Convention and Protocol

2.1 Introduction

The London Convention 1972 prohibits dumping except in accordance with a permit and then sets out the requirements for, and factors to consider, in granting permits. The Convention was updated 1996 in a new instrument called the London Protocol, which came into force in 2006. The London Protocol is a new and separate instrument that resulted from a review of the London Convention. The London Protocol supersedes the London Convention between London Protocol Contracting parties which are also Contracting Parties to the London Convention. The Protocol will not replace the London Convention until all members of the London Convention are also Parties to the Protocol.

In the Convention "Dumping" is defined in Article III (1)
(a) "Dumping" means:

(i) any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea;
(ii) any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea.

(b) "Dumping" does not include:

(i) the disposal at sea of wastes or other matter incidental to, or derived from the normal operations of vessels, aircraft, platforms or other man-made structures at sea and their equipment, other than wastes or other matter transported by or to vessels, aircraft, platforms or other man-made structures at sea, operating for the purpose of disposal of such matter or derived from the treatment of such wastes or other matter on such vessels, aircraft, platforms or structures;
(ii) placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention.
(c) The disposal of wastes or other matter directly arising from, or related to the exploration, exploitation and associated offshore processing of sea-bed mineral resources will not be covered by the provisions of this Convention.

Trends in dumping volumes of various waste categories regulated under the Convention are available at:
http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx

2.2 Other International Conventions

The London Protocol and its predecessor the London Convention are among a number of international laws and treaties that complement each other to protect the worlds oceans from a variety of activities. Details of Global and Regional Conventions are provided in Part 2 Section 5 of the WAG TS.

Also, details can be found on UNEP's Regional Seas website at:
http://www.unep.org/regionalseas/

3. Part 3: Processes

3.1 Step 1. Dredged Material Characterisation

Guidance on characterizing dredged material can also be found in Part 3, Step 7 of the WAG Training Set and in Chapter 4 of the Waste Specific Guidelines.

3.1.1 Introduction

Steps for waste characterisation of dredged material include measuring and testing for specific characteristics to help determine the physical, chemical and biological properties of the material.

A variety of assessment methods can be employed to determine material characteristics from simple observations to laboratory testing. A description and characterisation of the dredged material is required to determine; (1) if there are alternatives to sea disposal; (2) the basis for deciding whether or not it can be disposed at sea and (3) to help establish appropriate Permit Conditions if the material is acceptable for sea disposal.

Many permitting authorities will engage with applicants on prevention and management options (see Step 2) prior to undertaking a full characterisation of the waste, so Steps 1 and 2 may be iterative rather than sequential. For example, in countries where no national Action List of contaminants (Step 3) is available, then an investigation of potential sources of contamination can inform what analysis needs to be undertaken.

3.1.2 Exemptions from more detailed characterisation

Dredged material may be exempted from a full characterisation if any of the criteria listed below are met:

1. dredged material is excavated from a site away from existing and historical sources of appreciable pollution, so as to provide reasonable assurance that the dredged material has not been contaminated, or
2. dredged material is composed predominantly of sand, gravel and/or rock, or
3. dredged material is composed of previously undisturbed geological materials.

Some form of physical characterisation may need to be carried out to determine criteria 2 and 3 above. Dredged material that does not meet one of these criteria will require further characterisation to assess its potential impact.

3.1.3 Dredged material sampling

Both the physical and chemical characterisation of dredged material requires representative samples to be taken of the proposed dredge area for analysis.

Therefore a survey of the area to be dredged should be carried out. The distribution and depth of sampling should reflect the size and depth of the area to be dredged, the amount to be dredged and the expected variability in the horizontal and vertical distribution of contaminants.

Grab samples are usually sufficient for samples of surface sediment. Core samples can be taken where the depth of dredging and expected vertical distribution of contaminants suggest that this is warranted. Sampling from disposal vessels or barges is not recommended for permitting purposes (OSPAR 2009). See Mudroch and MacKnight (1994) and Mudroch and Azcue (1995) for further information.

Table 1 below is taken from the OSPAR Guidelines for the Management of Dredged Material (OSPAR 2009) and gives an indication of the number of recommended separate sampling stations required to obtain representative results, assuming a reasonably uniform sediment in the area to be dredged:

Amount Dredged m^3	No. of stations
Up to 25 000	3
25 000 - 100 000	4 – 6
100 000 - 500 000	7 – 15
500 000 - 2 000 000	16 – 30
>2 000 000	extra 10 per million m^3

Table 1. Recommended number of sample stations for proposed dredging material volumes (OSPAR 2009).

The number of sample stations can also be determined on the basis of the area to be dredged. For further guidance on sampling see the LC/LP Guidelines for the Sampling and Analysis of Dredged Material Intended for Disposal at Sea (IMO 2005)

3.1.4 Physical Characterisation

The physical composition of the dredged material is one of the most obvious and easily collected pieces of information that can be used to reach conclusions about whether that material can pose a hazard to the environment. Evaluation of the physical characteristics of sediments for disposal is necessary to determine potential impacts and can be used to inform a decision on whether or not to allow disposal at sea and also establish the need for subsequent chemical and/or biological testing.

Most natural and anthropogenic contaminants (e.g. trace elements and organics) tend to be associated with the finer particles in sediments, mainly silts and clays which are less than 63 µm in diameter. Therefore, knowledge of whether the dredged material contains silt or clay is very helpful as it has greater potential to contain contaminants. Dredged material composed predominantly of coarse grained materials, e.g., rock, gravel and sand, have a low potential to carry significant amounts of chemical contaminants. For example, sand containing little or no silt or clay will usually be relatively free from contamination and could therefore be exempted for further characterization in line with the criteria listed in Section 3.1.2.

Based on this knowledge, a simple visual and textural assessment can be used as a low-tech screening approach to determine likelihood of contamination. In addition, the relative homogeneity of the material can be used to determine the likelihood of sediments containing contaminants by examining: (1) whether sediments are recent or historic deposits when cross-referenced with knowledge of human activities and (2) whether any known surface deposits of contaminants might be mixed into underlying sediment layers.

A more detailed way of physically characterising sediment is to complete particle size analysis (PSA). Particle size analysis is quantitative and enables spatial and temporal comparisons of data. There are many different methods available, of varying complexity. Therefore the method chosen depends in part on the nature of the material being characterised. Whatever method that is selected should be used consistently over the area to be characterised to ensure comparability of the data used in the subsequent evaluation.

The methods outlined below are simple ways of achieving physical characterisation of sediment:

- Visual and textural description
- Rapid mud assessment
- Wet sieving a sample to produce a summary Particle Size Distribution (PSD)

Visual description - Visual descriptions of sediment samples are completed to supplement particle size distribution data. They aid determination of the mineral content, presence of shell material and organic material visible in the wet sample before analysis has commenced. Such visual assessment can help to build a set of assumptions on the likelihood and distribution of any contamination in the sediments in question (i.e. can oil, paint flakes, debris be seen?). They are subjective. The description should contain the following points:

a) colour,
b) homogeneity (presence or absence of stratification),
c) the presence or absence of animals (as an indication of bioturbation),
d) smell,
e) visual contamination (*e.g.* oil sheen, paint flakes etc.),
f) textural description (is the material gritty or smooth, see below).

Textural description - To determine the textural description, first remove a representative subsample of sediment into a sample container, for example, a foil tray. The description of the sample needs to include details of larger or single particles present such as large shell or gravel pieces.

Add some water to the sample container, stir round and begin observations of the sediment. Make an evaluation of the amount of mud material present stirring and tipping off water/mud i.e. if there is not very much material left after tipping off mud (fine material) then this sample would be identified as mud/very muddy depending on what has been left in the sample container. Try to characterise the sediment in the following terms: presence of gravel (coarse, cobble etc), sand (coarse, medium, fine, very fine) or mud, presence of clay lumps, colour of sediment, visible shell fragments with description or identification of shell if possible, plant matter, coal particles. The use of a sediment-sizing wheel is invaluable in assisting in this process (Figure 2). Include as much detail about the sediment as possible. Include any indication of influence of man, such as paint fragments, broken glass, cigarette butts, clinker (mining waste) and pieces of cloth within the description.

Figure 2: Sediment sizing wheel

Rapid mud assessment

Rapid mud assessment is a quick method that can be used to indicate relative mud content. It gives a rough estimate but it should be understood that flocculants (aggregated particles) will be included within the sand, and therefore this method may give higher estimates of sand than using traditional PSA methods.

Place a defined quantity of sediment in a tube. Add water (preferably from the source the sample was collected from – i.e. for marine sediments use seawater). Make sure the sample is fully disaggregated. Dispersants, such as sodium hexametaphosphate, may be required and advice as to concentrations will need to be checked. Shake the sample until it is fully mobile and then allow the sediment to settle out in layers. The top layer is representative of the mud content, and the depth of this relative to the depth of the rest of the sample will give an approximate measurement of mud content.

Wet sieving

A summary PSA using minimal equipment (2 sieves) can be used to give quantitative results.

- Place a 2 mm sieve over a bucket. Add the sample to the sieve and wash sediment <2 mm through the sieve into the bucket. Remove the >2 mm material and allow to dry. Record the weight of the sediment >2 mm.
- Place a 63 µm sieve over a bucket. Tip the water and sediment <2 mm into the 63 µm sieve and gently drain this sediment through the sieve. Wash through with more water until the water running through this sieve is clear and no more mud (sediment <63 µm) is present in the 63 µm sieve. Some disaggregation may be required. Remove the >63 µm sediment from the 63 µm sieve and allow to dry (air dry). Record the weight of the sediment <2 mm, >63 µm.
- Allow sediment <63 µm to settle out from the water in the remaining bucket. Drain off the water. Remove the <63 µm sediment from the bucket, allow the material to dry and record the weight of the sediment <63 µm.
- Convert the individual weights into percentage gravel, sand and mud.

3.1.5 Chemical characterisation

Chemical testing of dredged materials mainly entails quantifying concentrations of contaminants and the determination of Total Organic Carbon (TOC). This chapter will address the analysis of contaminants.

Contaminants monitored in dredged materials are typically priority substances of either an organic, organometallic or inorganic nature. Organic contaminants include polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs), polybrominated diphenyl ethers (PBDEs), organometallics include organotins such as tributyl tin (TBT), while inorganic compounds consist of elements. Many of these determinands have been introduced to the marine environment from anthropogenic sources. Information on deriving contaminant action lists, action levels and their application can be found in Step 3 Action List.

There are three options for testing the chemical content of the samples which will have differences in terms of complexity and cost:

- Preliminary assessment, e.g. smell, source (marine /terrestrial source), visual etc
- Laboratory testing, by a qualified/certified analytical laboratory
- Send the samples abroad, for analyses by a qualified/certified analytical laboratory

Preliminary assessment

In determining whether to test dredged material, and what compounds to test for, there are a number of steps which can be taken to minimise the amount of analysis needed.

The determination of PCBs, PAHs and Tri-Butyl tin compounds and its degradation products will not be necessary in circumstances where the sediments are very unlikely to be contaminated with these substances. The relevant circumstances are:

- sufficient information from previous investigations indicating the absence of contamination is available; or
- there are no known significant sources (point or diffuse) of contamination or historic inputs; and
- the sediments have very low amounts of fine material; and/or the content of total organic carbon is low.

Samples that have a high proportion of fine fraction potentially have higher levels of contamination.

Rudimentary tests involving smell, colour and a visual inspection can be used, particularly to ascertain if high levels of PAH's are present. For example samples that are highly contaminated with hydrocarbons tend to have an oily smell and may be black in colour, although it is important to note anoxic material is also often black in colour (in which case the smell could be like rotten eggs), as is often the case with organic rich material. Sediments containing PAHs would also give off an oily sheen when mixed with water and shaken.

Some preliminary desk analysis can also help to determine what to test for. For example if the area is known to be contaminated through previous pollution incidents or ongoing inputs such as from industry or sewage works, then that information can influence what to consider measuring. Similarly knowledge of historic activities in an area can also help direct the analysis. There are also times when analysis may not be necessary, for example if the material to be deposited is glacial in origin or if it comes from areas of an approach channel where contamination is highly unlikely.

Laboratory testing
The analytical methods for potentially relevant parameters range from simple, straightforward and reasonably available throughout much of the world, to complicated, difficult and not practically available in many countries.

It would be counterproductive to request analyses that cannot reliably and reasonably be performed in association with the project being evaluated. For example, if a given chemical analysis could only be done after several days of transport to get the samples from the dredging project to the laboratory at tropical temperatures, and in addition, the performance of that analyses was new to the laboratory (or they were untrained or unequipped to reach the required detection levels), the results may be of little value.

No matter how desirable sophisticated analyses may be, it is usually best to request analyses that are logistically practical and within the demonstrated capabilities of the available laboratories. However, it may be appropriate to encourage the available laboratories to progressively expand their capabilities.

Further information on sediment analysis can be found in LC/LP 'Guidelines for the Sampling and Analysis of Dredged Material Intended for Disposal at Sea' (IMO 2005).

Sending samples abroad
If analyses are required and there is no/limited access to appropriate laboratory facilities within a country then an option is to have the samples tested abroad (see Case Study, Part 5). In some countries certain analytical methods may be considered too advanced, however in other countries it might be more routine and inexpensive and therefore worth exploring.

There are many reputable laboratories in various countries that can test the samples for a suite of analysis. Laboratories generally provide instructions of how to take, store and send samples. Be sure to use a laboratory which uses appropriate methods. Countries that are already Contracting Parties to the Convention should be able to provide advice on selection criteria for such laboratories.

3.1.6 Biological characterisation
If the potential impacts of the dredged material to be disposed cannot be adequately assessed on the basis of the physical and chemical characterisation, biological characterisation can be undertaken. This usually involves biological testing (bioassays); however use of such tests to evaluate dredged material is considered beyond a low technology approach therefore it is not considered here. Further guidance on biological testing is provided in PIANC (2006).

In a low technology environment an assessment of the biological community could be simply undertaken by obtaining a sample of the sediment to be dredged and examining the marine life it supports. If there is marine life present then this would suggest that the sediment is not having significant negative impacts on the biota. If the sediment was devoid of biota then this would indicate the opposite. The sediment sample from the proposed dredge area could also be compared to sediment of similar composition from a nearby area where sources of contamination are less likely.

3.1.7 Dredging and discharge method
Along with the physical nature of the material to be dredged, the chosen dredging and discharge method can influence the nature of material and its behaviour after disposal. There is a wide diversity of dredging plant and methods. The main types of dredgers used for dredging projects throughout the world are Cutter Suction Dredgers (CSD) and Trailing

Suction Hopper Dredgers (TSHD), both a type of hydraulic dredger, and mechanical dredgers including Backhoe Dredgers (BHD) and Grab Dredgers (GD). Discharge methods include direct pipeline discharge, hopper dredger discharge through bottom doors, discharge from barges and direct mechanical deposition.

Hydraulic dredgers use a centrifugal pump and pipe system to raise loosened material from its in-situ state in suspension to the surface. Hopper dredgers discharge a mixture of water and solids. At the disposal site the bottom doors of the hopper open and the mixture falls to the seabed as a jet of high-density fluid. Most of the material will come to rest where it falls and some may travel away from the area of impact radially. Some finer material may remain in suspension forming a turbidity plume.

Mechanical dredgers use mechanical excavation equipment for cutting and raising material. Mechanically dredged material discharged from barges is often at a density close to that prior to it being dredged. The disposed material will fall quickly to the seabed and only a small amount would remain in suspension.

Dredged material discharged through a direct pipeline is generally liquid slurry however it can contain coarse material such as sand and gravel or even clay balls. The coarse material would fall rapidly to the seafloor while the finer particles that are mixed with the process water would form a fluid mud mound on the seabed. There is also likely to be a proportion of fine material that would remain in suspension forming a turbidity plume as with discharge from a hopper dredger.

Further information on dredging and discharge methods can be found in CEDA & IADC (2008), Herbich (2001) and Bray et al (1996).

3.2 Step 2. Waste prevention audit and management options

Guidance on the use of waste prevention audits is given in the generic WAG, Chapter 2 and Part 3, Step 2 of the WAG Tutorial. Similarly, WAG Chapter 3 covers management options that are part of the overall waste assessment framework.

3.2.1 Introduction

The waste prevention audit is an approach used to identify where contaminants present in the sediments originate. The aim of this phase is to identify ways that these sources can be reduced in the future either through actions of the project sponsor or other organisations. These actions will result in cleaner sediments in the future and will help to reduce harm to the marine environment.

It is important first to assure the need for dredging and disposal has been clearly established and to ensure that the quantities of sediment to be dredged are minimised as far as is practicable.

Once the material has been characterised, waste management options, including alternative uses, should then be considered to indicate whether there are any other practicable options to re-use, recycle, treat or store the dredged material.

The potential value of dredged material as a resource should be considered by steps to identify opportunities for beneficial use of the sediment. Where the characteristics of dredged material are such that it is deemed not acceptable for sea disposal, then other management options should be considered, such as treatment and storage in confined disposal sites on land or at sea (PIANC 2008).

3.2.2 Is dredging and disposal necessary?

There are a number of dredging activities which may give rise to the need to dispose of sediments. Examples include:

- Capital dredging - for navigation, to enlarge or deepen existing channel and port areas or to create new ones; and for engineering purposes; e.g. trenches for pipes, cables and immersed tube tunnels, removal of material unsuitable for foundations, removal of overburden for aggregate extraction;

- Maintenance dredging - to ensure that channels, berths or construction works are maintained at their designed dimensions (i.e. counteracting sedimentation and changes in morphology); and

- Remedial or environmental (clean-up) dredging - deliberate removal of contaminated material from the marine environment for human health and environmental protection purposes.

Before beginning a full assessment of the material to be dredged and management options, it is important to assure that the need for dredging has been established. From an environmental and also an economic perspective, it is worth asking the questions '*Is dredging necessary?'* and if so *'Can it be reduced further*?' In some circumstances, dredging may be avoided or reduced, therefore removing or reducing the need for sea disposal.

3.2.3 Waste prevention audit

As introduced above, the waste prevention audit for dredged material should focus on the sources of contamination to try and develop an understanding of how an area has historically become contaminated. Then the audit should seek to identify potential control options to prevent or reduce further contamination of sediments.

3.2.4 What are the sources of contamination?

Contamination of estuarine and coastal marine sediments, both as a consequence of historical and present day inputs, presents a continuing problem for the management of dredged material. Contamination can enter marine sediments from point or non-point (diffuse) sources. Point sources enter at a specific site, such as a discharge pipe or through an accidental spill, and are therefore more readily identified. Non-point sources generally result from the wide use of a substance over a wide area. They can result from land use activities such as urban development, mining or agriculture and enter the marine environment through run-off or groundwater seepage. Sources of contamination in marine sediments include:

- *Agricultural practices*; which can provide inputs such as pesticides from upstream catchment areas.
- *Industrial practices*; such as general discarding and discharges directly into the marine environment or indirectly through rivers (e.g. from factories, power plants, industrial sites or mines) mainly resulting in heavy metals, organotins and oil based contaminants.
- *Urban discharges*; including road run-off which can contain heavy metal, oil and PAHs.
- *Accidental spillages*; which can be direct into the marine environment or reach it through drains and can include leakage from engines or storage tanks.
- *Erosion or disturbance of river and/or estuary banks and beds*; this is where *in situ* sediments contaminated through historic activities (such as those described above) are remobilized creating a current source of contamination. Erosion could occur through natural events such as storms or flooding, disturbance could occur as a result of construction or dredging operations.

Case Study 1 (Part 6) focuses on dredged material assessment in Karachi, Pakistan and provides an example of sources of oil pollution in the harbour sediments.

It is also important to consider how the contaminants arrived in the sediment. This is often referred to as the ‘pathway’. For dredged material, the main pathway is usually from an upstream source. An upstream pathway is one by which contaminants can move from a source, through the aquatic environment, to the location where the sediment needs to be dredged. However there may also be a downstream pathway, whereby the contamination is already in the sediment and if the sediments are disturbed (e.g. through dredging operations) then the contaminants can be remobilised into the water column and become a fresh source of pollution.

3.2.5 Can contamination be controlled?

If the waste prevention audit identifies contaminant sources, then these may have the potential to be controlled to prevent pollution into the future. Therefore, the next step would be to identify control (or prevention) options for contaminant sources. This should be achieved through the implementation of waste prevention strategies.

Control options involve identifying mechanisms to reduce the sources of contamination. Low tech options would mainly relate to physical controls, these are most effective in reducing new sources of pollution and tend to reduce costs for disposal, for example:

- Settling ponds (e.g. settling basins or interceptors): These can be employed where fine particles are washed off a site due to either the process water from a specific activity or natural drainage. Drains or run-offs can be diverted to pass through settling ponds where the flow of surface waters is slowed to facilitate the settling and consolidation of suspended solids and any contaminants bound to them. The contaminated sediment is then collected before it can enter the water body and can be cleaned out periodically and dealt with as a waste on land. Settling ponds can be set up for both oil and particulate based matter and could be employed wherever stockpiles of materials have been identified as a potential source of contaminants; an example would be port terminals handling bulk cargos such as coal or metal ore.

- Filters (e.g. screens, scrubbers) mainly used in the sewerage industry, but could be used in conjunction with settling ponds to remove larger 'foreign bodies' from a discharge. However, these are unlikely to remove/ prevent the contaminants that are usually associated with dredged material from entering a water body such as heavy metals, PCBs, PAHs, organotins and pesticides.

- Agricultural buffer strips: Establishing vegetated buffer strips between agricultural land and water bodies can help to reduce entry of sediment and agricultural chemicals to the water by slowing run-off and trapping eroded sediment.

The most effective practical method of a control will be case specific and rely on the correct identification of the problem. In addition to the physical controls described, evaluations can be made of the industrial process contributing to the input pathways to reduce waste (WAG TS Step2 Part 3). Most physical controls will be mainly effective in reducing or preventing current and future contamination, however, they would be of limited use in preventing the remobilisation of sediments containing historical contamination. Any improvements that can be made to reduce contaminants entering the marine environment, however small, can over time have significant benefits.

3.2.6 Waste Prevention Strategy

If a completed waste audit reveals that opportunities exist for waste prevention at the source, a waste prevention strategy should be developed. The strategy needs to prioritise the quantities of waste or contaminants which are most likely to cause environmental harm.

The control of sources of contamination may be outside the jurisdiction of the organisation responsible for the dredging or the organisation applying this guidance. Therefore it is important to liaise with any public agencies (local, regional or national) involved with the control of point or non-point sources of pollution. Also liaise with private organisations (including industry) to inform them of the contamination issues associated with the waste and its consequences within the water body. Then, where possible, collaborate with all public agencies and private organisations in developing a strategic approach to dealing with the problem, where possible incorporating the Polluter Pays Principle.

3.2.7 Waste Management Options

Under the London Protocol an application to dispose dredged material shall demonstrate that consideration has been given to the following hierarchy of waste management options, organised below in order of increasing environmental impact:

1) Re-use or beneficial use
2) Offsite recycling
3) Destruction of hazardous contaminants
4) Treatment to reduce or remove hazardous constituents
5) Disposal on land or in water.

For dredged material the main management options employed are alternative/beneficial use or non-ocean disposal. Treatment can be used in combination with either option to make the sediment more suitable for a specific use or disposal.

3.2.8 Are there any beneficial uses?

It is estimated that more than 90% of dredged material is relatively uncontaminated, natural, undisturbed sediment and could be considered for a wide range of alternative uses (Bray, 2008). Depending on the physical and chemical characteristics of the material, there is a wide variety of alternative uses. Although not yet common practice in all parts of the world, there is a growing recognition that dredged material is a valuable resource and some countries do make extensive use of it, for example Japan uses more than 60% of its dredged material (Bray, 2008).

There has been an increased focus on the alternative uses of dredged material over recent years. PIANC EnviCom set up a working group to study worldwide practice and compiled a report (PIANC, 2008) which includes guidance on the assessment of options for alternative use. The report identified a range of potential uses and these were classified into two broad categories, engineering uses and environmental enhancement:

Engineering uses

Dredged material can be used as an alternative for other materials in engineering projects. This can include use as construction materials for landfill and foundations, beach nourishment for flood and coastal defence, land improvement and for the isolation of contaminated sites such as upland industrial sites. It can also be used for capping dredged material disposal sites where a continuous layer of clean dredged material (e.g. sand) is placed upon contaminated dredged material to isolate it. The use of the dredged material for beneficial use will mainly depend on its quality, taking into account its physical nature and contamination levels. Generally material associated with capital dredging such as rock, gravel and sand are considered the most valuable for use in engineering projects. For example, sands and gravels are valuable for land creation schemes where the land is to be used for building. However, material more associated with maintenance dredging activities, such as silts and clays, consolidate over a much longer period and would only be suitable to build on after a suitable length of time. Some site specific uses for different types of dredged material in engineering projects are included in Table 2 below.

		Dredged material sediment type				
	Dredged material use options ***Construction materials***	Rock	Gravel	Sand	Clay/Silt	Mixture
1	Road foundations	*	*	*	*	*
2	Replacement fill	*	*	*	*	*
3	Dikes	*	*	*	*	
4	Mounds			*	*	*
5	noise/wind barriers			*	*	*
6	Land reclamation		*	*	*	*
7	Land			*	*	*
8	Stabilisation		*	*		*
9	Sealing of CDF's (confined disposal facilities)				*	
10	Capping of disposal sites, landfills		*	*	*	*
11	Capping of contaminated sediments		*	*	*	
12	Rehabilitation of brownfields			*	*	*

Table 2. Site-specific material selection for engineering use (from PIANC 2008).

Environmental Enhancement

Dredged material can also be a valuable resource to enhance the environment and uses include habitat creation and enhancement, aquaculture and recreation. Another use is sustainable relocation. In certain situations regular removal of sediments by dredging can cause physical problems in estuaries such as erosion to intertidal banks and saltmarshes. Recycling the dredged sediment within the natural transport system can mitigate adverse effects by maintaining the sediment budget; this is sometimes referred to as sustainable relocation. Dredged material can also be used in agriculture, for example, placement areas providing productive soils and areas for livestock. But these uses are mainly associated with sediments dredged from river systems as saline dredged material would require washing with fresh water to reduce salinity.

Therefore it is largely the physical and chemical nature of the dredged material that determines what use options are available. Evaluation of the site proposed for beneficial use will also be required to determine the likelihood of success and prevent interference with other users and impacts to natural resources.

3.2.9 Can contaminated dredged material be treated?

The presence of contamination does not necessarily rule out the use of dredged material as treatment can be employed to reduce, remove or immobilize contaminants. Treatment in relation to use of dredged material generally refers to material that has been removed since *in situ* treatment is not usually an option. PIANC (2008) and CEDA & IADC (2008) consider a wide range of treatment technologies available. However, contracting treatment techniques is complicated and can demand high levels of technology and highly skilled personnel. Therefore, treatment is not considered further in this training set. For further information, see the references quoted above.

3.2.10 Confined disposal

Confined disposal is where dredged material is placed into a secure area where it is physically contained. Confined disposal facilities (CDFs) and contained aquatic disposal (CAD) cells are two techniques that are available alternatives. CDFs are mainly diked structures that have been built to isolate the dredged sediments from the surrounding waters or soils and ground water both during and after deposition. CDFs can be the final destination of sediments or can be used as temporary storage sites. They can be constructed in the aquatic environment as islands or on land. On occasions CDFs have been used to confine clean dredged material where other options are not feasible for economic or environmental reasons (e.g. physical impacts of sea disposal are unacceptable). Basic CDF options and their suitability for use are provided in CEDA & IADC (2008). CADs are underwater pits that are used to contain the contaminated sediments. They can be naturally occurring bottom depressions, sites of previous marine sediment mining (e.g. sand or gravel mining), or they can be pits specifically dredged to contain the contaminated sediment (Fredette 2006).

3.2.11 Disposal management techniques

If the dredged material is deemed acceptable for disposal at sea and no beneficial use options or land-based disposal options (confined or unconfined) are practicable, then it can be considered for disposal at sea. Unconfined sea disposal is the most common method employed, however, where concerns exist over the potential for sediments to re-suspend and impact sensitive habitats or species, then semi-confined disposal can be used.

- Unconfined (open water) sea disposal is the deposition of sediments at a designated area on the seabed. The material disposed would generally form mounds on the seabed, but whether the sediment remains or is transported away from the site will depend on site specific conditions, mainly the currents and/or wave action. Depending on the potential for re-suspension and erosion of the deposited material, disposal sites are distinguished as non-dispersive (retentive) or dispersive.

- Confined sea disposal is where some kind of lateral confinement is used to limit or stop the spread of the deposited material once it is on the seabed or where a cap of cleaner material is placed over the contaminated sediment. Natural or artificial depressions or purpose-constructed pits or berms and dikes can be used to confine the material to an area on the seabed.

3.2.12 Evaluation of Dredged Material Management Options

Waste management options for dredged material have been described above. The following steps summarize the evaluation of those options that have been discussed in the previous sections;

1. A description and characterisation of the material to be dredged (in line with Step 1 of this training) to enable consideration of alternatives and the basis for a decision as to whether the dredged material can be disposed at sea.

2. Identify opportunities for the beneficial use of dredged material,

3. If the material to be dredged is contaminated, can it be treated and if so, can it then be used beneficially.

4. If beneficial use or treatment is not feasible, can it be stored in confined disposal sites on land or at sea.

5. The next step is to ascertain the comparative risks to human health and the environment from using alternatives (beneficial use/confined disposal) and disposal at sea.

6. Compare the costs of using alternatives and disposal at sea.

If the alternatives to sea disposal have no disproportionate difference in costs and comparable impact to human health and the environment, the London Convention and Protocol WAG favours selection of the alternative. For dredged material, the cost of sea disposal may often be less than the alternatives, however it is important to take into account any related monitoring costs in addition to damage to the marine environment and possible conflicts with other legitimate users of the sea.

3.3 Step 3. Action list

Information on Action Lists is provided in the generic WAG, Chapter 5 and Part 3, Step 3 of the WAG Training Set. In 2008 LC/LP published a guidance document on the selection of Action Lists and the development of Action Levels for dredged material proposed for disposal at sea. The guidance document is entitled 'Guidance for the Development of Action Lists and Action Levels for Dredged Material' this can be found at: http://www5.imo.org/SharePoint/blastDataHelper.asp/data_id%3D25196/DredgedMaterialActionList.pdf

3.3.1 Introduction

An **Action List** is a set of chemicals of concern that can be used for screening dredged material for its potential effects on human health and the marine environment.

Action Levels establish thresholds that provide decision points that determine whether sediments can be disposed of at sea. The Action Level will specify an Upper Level and may also specify a Lower Level. The Upper Level should be set to avoid acute or chronic effects on human health or on marine organisms. Below the Lower Level, there should be little concern for disposal at sea.

In line with the WAG the application of an Action List, and its levels, is used to enable authorities to categorize the dredged material in terms of its suitability for disposal at sea. Action Lists and Levels are of use to non-contracting parties and those countries aspiring to be contracting parties as they promote a consistent and transparent scientific basis by which to categorise or assess dredged material based on the level of risk they may pose to the marine environment upon disposal. A jurisdiction that has developed a National Action List and Action Levels will be in a better position to make sound permit decisions and to be in compliance with the requirements of the LC/LP. Action Levels can also provide feedback for compliance efforts, for further assessment or for monitoring.

Those jurisdictions with limited experience that wish to adopt an Action List and Levels can seek additional guidance and support to select the most suitable approach and to adapt it as needed to their legal and environmental circumstances. In the first instance it is important to try and achieve a balance between the best level of assessment possible and the availability of resources and capacity. The starting point should be practices that are achievable in the short term, with a view to continuing improvement as capacity and expertise are acquired.

The Action List Guidance describes the following three main stages of the process of selecting Action Lists and Action Levels and proposes options that are available:

1. Identification of the chemical, biological, or physical characteristics that will make up the Action List.
2. Benchmarks need to be set for each characteristic on the Action List.
3. Levels are set by integrating the relevant characteristics and benchmarks to form a decision rule.

Definition of Major Terms

The following terms **characteristic, metric** and **benchmark** define the tools that are used to evaluate some aspect of the environment.

A **characteristic** is an attribute of the dredged material (e.g., silt, copper, mercury, petroleum compounds, pathogens).

A **metric** is a measurement that can be made on the characteristic (e.g., percent silt).

A **benchmark** is a point on the range of the metric (e.g. 10% silt, 4 mg/kg copper) that is used to identify where environmental concern may be low or high for that characteristic. These can be referred to as the lower benchmark and upper benchmark.

An Action List therefore comprises a number of characteristics to be considered for measurement in the dredged material.

An Action Level is a decision rule based on the findings of one or more characteristics in comparison to the respective benchmarks.

The three main stages of selecting Action Lists and Action Levels are outlined below to establish some principles for the application of a low tech approach.

3.3.2 Selection of an Action List

A Dredged Material Action List is a list or inventory of dredged material characteristics and their metrics that a jurisdiction decides are important to consider in order to make permit decisions. The LC/LP require contracting parties to develop a National Action List, however they can be equally developed at a regional or more local level by those employing this Training Set extension.

In developing an Action List, it is important to consider what potential concerns are created by the disposal of dredged material, for example: what assets or resources need to be protected in their jurisdiction/area? This consideration should lead to a determination of what needs to be measured and assessed.

Selection of the characteristics and metrics in an Action List should be based on knowledge concerning the characteristics of dredged material in the area/country where the list is to be used. For chemical characteristics, for example, a list of contaminants of concern should be developed. The list should be constructed from information on historical or present day inputs into an area as described in Step 2 of this training set.

In practice, an Action List will be developed by assembling a list of characteristics that will be used to perform a regulatory evaluation of dredged material.

3.3.3 Establishing Upper and Lower Benchmarks

Once an Action List has been developed, benchmarks need to be established for the characteristics. Each characteristic (e.g. cadmium, survival, etc.) will have a metric (what is being measured: e.g. sediment concentration (mg/kg dry weight). The benchmarks are the levels for a particular characteristic:

- lower benchmark - below which there would be little concern or
- upper benchmark - above which there would be concern due to increased risk or increased probability of effects.

Once benchmarks are established for the characteristics on the List they are used to establish the Upper, and if desired, may be used to establish Lower Action Levels.

Benchmarks for physical, chemical or biological characteristics can be set based on knowledge of background or ambient conditions in comparable areas that have not been impacted by disposal operations. Benchmarks are often developed using a ***reference-based approach*** (comparing to background or ambient conditions) or an ***effects-based approach*** (based on knowledge or direct observation of the effects of exposure).

The simplest approach is to use reference-based levels which are commonly used for setting lower benchmarks and Lower Action Levels, as it is reasonable to expect that levels that are similar to background levels and would therefore be unlikely to cause unacceptable effects. For example, the Lower Action Level may be set at the background concentration for the chemical of interest.

If employing an effects-based approach, the physical characteristics of the dredged material can be used to reach conclusions about whether the dredged material is unlikely to cause adverse effects on the environment, i.e. to establish lower benchmarks. For example, sediments found in areas of high current or wave energy and composed predominantly of coarse-grained sediments (e.g., rock, cobble and sand) have a low potential to carry significant amounts of chemical contaminants because of the relatively small surface area available for sorption of contaminants. Therefore, set quantitative or qualitative criteria should be used to define when sediment will be judged to be predominantly composed of such coarse-grained material.

Upper Action Levels should be set so as to avoid acute or chronic effects on human health, or on sensitive marine organisms. Therefore, any benchmarks used to establish Upper Action Levels should minimize the likelihood that dredged material could exceed such values but produce no effects at a disposal site (false negatives). Chemical benchmarks, particularly upper benchmarks, are often developed using an effects-based approach by making use of calculated or measured relationships between the concentration of the chemical(s) and some form of biological response. There are a variety of empirical and theoretical approaches that can be used to establish such levels and these are outlined in the Action Level guidance document.

Frequently, there will be insufficient capability, data, time or funding to ensure that benchmarks are set on purely scientific grounds and that all uncertainties in the methods and the data can be addressed. In order to proceed with a functional decision-making system in a reasonable time it is often necessary to take interim measures. Many jurisdictions may have limited information and simply decide to apply safety factors to benchmarks derived for other purposes, or set one benchmark as a multiple of another benchmark in an arbitrary fashion to help overcome a lack of data, or allow consistent decisions to be made.

When data are insufficient within a jurisdiction to calculate or derive benchmarks for specific characteristics on an Action List, upper and lower benchmarks can also be adopted directly from other jurisdictions as an interim measure (see Part 5 Case Study).

3.3.4 Setting Action Levels

Once benchmarks are established for the characteristics on the Action List, they can be used to construct Action Levels. The Action Levels are set by integrating the relevant characteristics and benchmarks to form a decision rule. This can be as simple as a pass/fail based on a single benchmark, or it can be more complex such as combining multiple lines of evidence in a weight-of-evidence approach.

- The Upper Action Level is intended to provide a definitive decision point where the dredged material may not be disposed at sea except in cases where control measures can be taken to manage the risks at acceptable levels.

- The Lower Action Level is that level below which a dredged material would be expected to have little potential to produce an adverse effect in the marine environment and for this reason can be disposed without the need for special management controls.

Figure 3 shows some of the types of information that can be used to set benchmarks for the characteristics on the Action List. As information from different benchmarks is incorporated into the decision rule for the Action Level, the confidence in the decision should improve as the weight of evidence accumulates to support a specific conclusion.

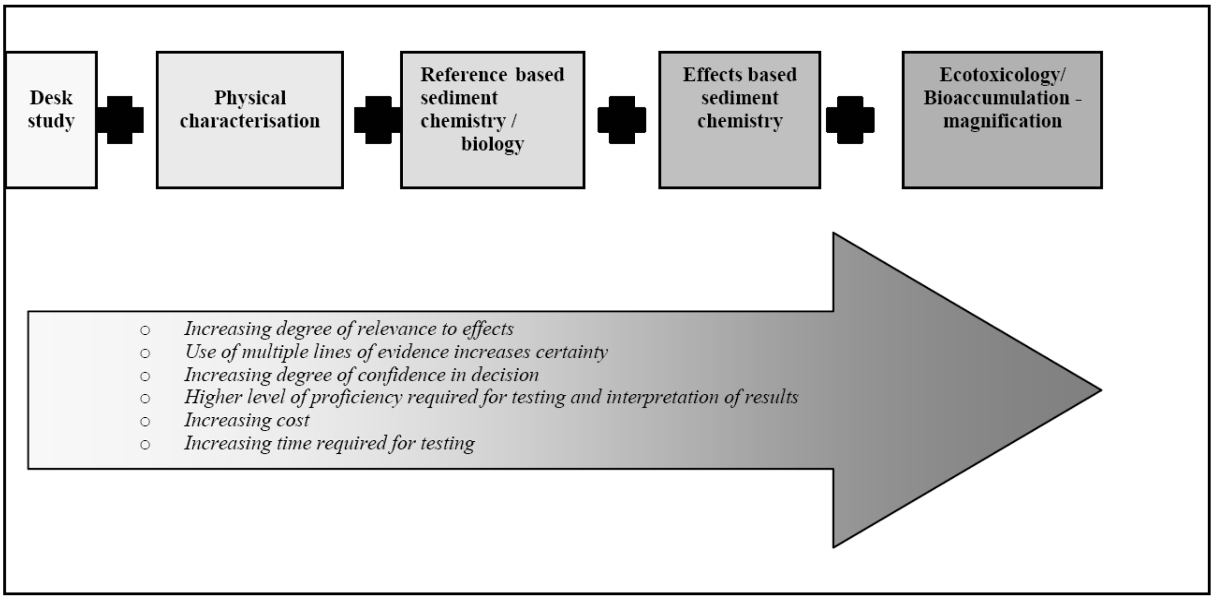

Figure 3. The types of information that can be used to set benchmarks for the characteristics on the Action List.

3.3.5 Simple Pass/Fail Action Levels

Simple pass/fail Action Levels offer the advantage of enabling clear, transparent and repeatable decisions that can be implemented with relatively little training and experience by a Permitting Authority.

In a simple approach (Table 3) the Action List consists of a series of contaminants (characteristics) that may be present in the material. Lower and upper benchmarks are established for each characteristic on the List. Using the simple approach, exceedance of any single upper benchmark would be considered an exceedance of the Upper Action Level. All characteristics of the sediment must be below the lower benchmarks to reach the conclusion that the material poses a low and acceptable level of risk to the marine environment and does not exceed the Lower Action Level. Sediments meeting neither of those situations would require additional investigation or evaluation before a decision could be reached.

Single characteristic Action Level Model				
Dredged material characteristic	Dredged material passes Lower Action Level when:	Lower benchmark (LB) mg/kg	Upper benchmark (UB) mg/kg	Dredged material exceeds Upper Action Level when:
Contaminant A	All values below Lower Benchmark	120	340	Exceedance of any Upper Benchmark
Contaminant B		75	88	
Contaminant C		25	420	
Contaminant D		0.5	2.7	
Contaminant E		50	170	

Table 3. An Example of a Simple Action Level Approach

The Upper or Lower Action Levels can be formulated in a number of ways. Below are several possible formats for formulating simple Pass/Fail Action Levels.

3.3.6 Lower Action Levels

Dredged materials below the relevant lower levels should be considered to be of little environmental concern in relation to sea disposal. The purpose of establishing Lower Action Levels is to efficiently screen out materials that pose a negligible risk to the marine environment and human health. Examples of Lower Action Levels based on (1) physical and (2) chemical characteristics are provided below:

1. *'The Lower Action Level is not exceeded if the material comprises greater than 80% rock and cobble and was dredged from areas distant/remote from known sources of contamination.'*

2. *'The Lower Action Level is not exceeded if the mean concentrations (in mg/kg or µg/kg) in sediment of all the following are below the lower benchmarks: Cd, Hg, PCB, PAH.'*

3.3.7 Upper Action Levels

Dredged materials that exceed Upper Action Levels cannot be disposed of at sea without the application of management techniques and processes. Upper Action Levels are intended to indicate the point above which materials will pose an unacceptable risk to the marine environment and human health. Examples of Upper Action Levels based on (1) chemical and (2) biological characteristics are provided below:

1. '*The Upper Action Level is exceeded and disposal is not permitted if the percent survival in a 10-day toxicity test is statistically lower in the dredged material, compared to the reference sediment*.'

2. '*The Upper Action Level is exceeded and disposal is not permitted if the sediment concentration (in mg/kg or µg/kg) exceeds any effects-based upper chemical benchmark on the National Action List e.g., Cd, Hg, PAH, PCB*.'

3.3.8 Between Lower and Upper Action Levels

In cases where the dredged material falls between the Upper and Lower Action Levels additional information would be required before a decision permitting disposal could be made.

Alternatively, a decision could be made to seek an different disposal option other than sea disposal, for example, in circumstances where the costs associated with additional assessment are expected to be larger than the differential between sea disposal and the next, least costly option.

Where a further assessment is required its purpose would be to address specific sources of uncertainty that prevent classifying the sediment as either suitable or unsuitable for sea disposal. For example additional sampling and analysis may be required to increase the spatial extent (i.e. a larger number of samples per unit area). This may determine that some discrete areas within the dredging zone may be suitable for disposal at sea while others are not, resulting in areas in the dredge zone where material is excluded from disposal at sea.

3.4 Step 4: Selecting a disposal-site

Guidance on selecting a dredged material disposal site can also be found in part 3, Step 4 of the WAG Training Set and in Chapter 6 of the Waste Specific Guidelines that supplement Annex 2 of the 1996 London Protocol.

3.4.1 Introduction

Selection of a site for the disposal of dredged material should try as far as possible to ensure that the disposal operation and the dredged material deposited on the seabed does not interfere with other uses of the sea and produce detrimental effects on the marine environment. Having defined disposal sites can greatly simplify the development and enforcement of management measures for disposal activities. In practice, disposal sites may already be in use or a new site may need to be selected.

The WAG Training Set outlines the steps to be followed in selecting a site:

1. Identify available areas within reasonable distance of the load site.
2. Determine requirements related to the characteristics of the dredged material.
3. Select candidate disposal sites and assess potential impact of disposal of the proposed material at these sites.
4. Evaluate acceptability of probable impacts at candidate sites.
5. Compare potential impacts among the remaining sites.
6. Select the site from among those where adverse impacts are judged to be acceptable.

The potential environmental effects of the disposal operation depend on the hydrodynamic (or water movement) characteristics of the site, the properties of the dredged material and the behaviour of that material during and after disposal. The stages to be considered in the selection of a dredged material disposal site are outlined below and suggestions of how they can be approached from a low tech perspective.

3.4.2 Identifying Available Areas for a Disposal Site

This step is essentially a broad brush initial evaluation of disposal sites options from which one or perhaps a few options are selected for more detailed evaluation.

Firstly determine the area where dredged material can be reasonably transported and disposed taking into account economic and operational feasibility as well as first hand information. This area is referred to as the 'Zone of Siting Feasibility' or ZSF (Pequegnat, 1988). Then, within the ZSF, information should be compiled on present and potential uses that may be incompatible with the disposal operation. These can include:

1. fishing and shellfish grounds (commercial and recreational),
2. spawning, feeding and nursery grounds and migration routes of important fisheries,
3. migration routes of marine mammals,
4. aquaculture sites,
5. present and potential areas of special importance for conservation and scientific purposes such as marine protected areas, coral reefs or seagrass beds.
6. renewable energy sites such as offshore wind farms and wave and tidal stream devices,
7. engineering uses of the sea floor, such as cables and pipelines,
8. seabed mineral resource extraction areas,
9. shipping lanes and anchorages,
10. military exclusion zones, marine archaeological interests,

11. beaches and other areas used for recreational purposes, and
12. intake sites for industrial uses such as cooling, desalination and aquaculture.

Some or all of the uses described above may require a buffer zone around them to ensure that they are protected adequately.

Information on the activities above can be gained through approaching relevant regulatory bodies or organisations involved in the activities or through local knowledge. For example local fishermen may have a wealth of knowledge on fisheries and fishing grounds but also knowledge of other uses of the sea in the ZSF.

The information gathered can be presented through Geographic Information Systems (GIS) enabling the remaining areas potentially suitable for disposal sites to be identified. If GIS software is unavailable, hydrological charts or maps can be used with simple tracing paper overlays or clear acetate sheets on an Over Head Projector (OHP) to mark the location and spatial extent of marine users/activities. The use of an OHP can provide a good visual aid for presenting the findings in a clear and informative manner. Once this 'picture' of uses and users has been built up potential areas for further evaluation can be identified.

If the internet is accessible, Google Earth® (www.google.com) can be used for simply viewing images of the area. It is easily downloadable and available free of charge. It may also be possible to see the presence of natural turbidity plumes and the direction of incoming waves (Figure 4) from Google Earth® images. Once captured, images can be used in further consultation with other stakeholders. In a few years, bottom topography information may become more accurate and available, therefore it is recommended to follow the development of satellite based observation.

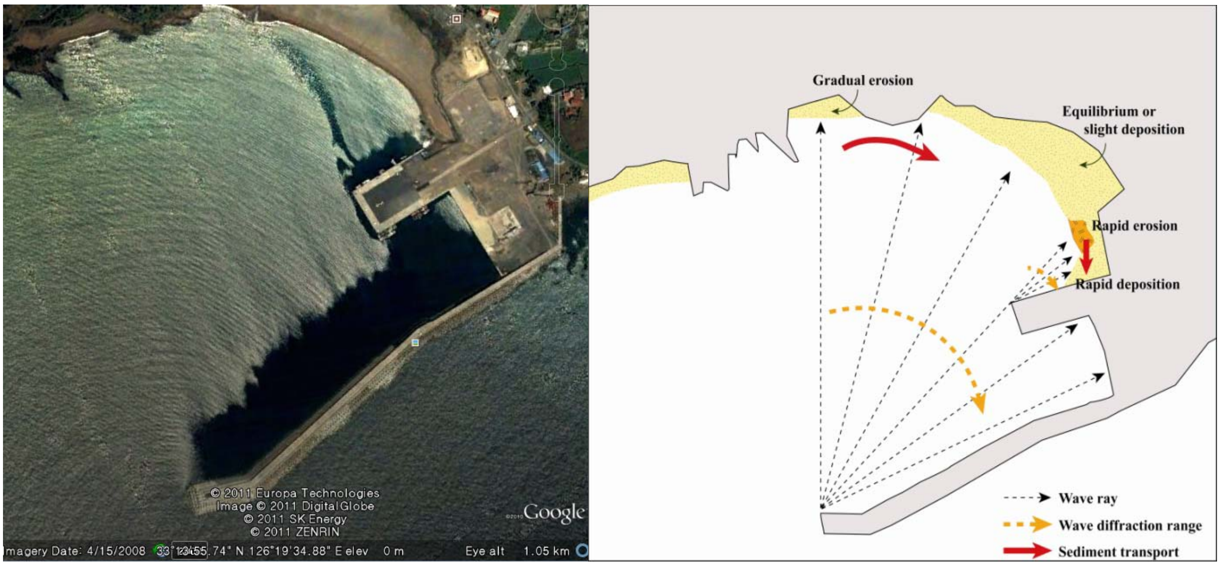

Figure 4. Wave crest distribution approaching Hwasun harbour, Jeju Island.

3.4.3 Information on Dredged Material Characteristics

The physical characteristics of the material to be disposed of are used to determine the suitability of a potential disposal site. Low tech methods for the physical characterisation are described in Step 1 Waste Characterisation. The most important physical characteristics are grain size and the cohesiveness/degree of consolidation as they contribute (along with environmental factors) to how the dredged material behaves after disposal. Important considerations include:

- *Dispersion direction and distance of associated plumes*; fine grains in the dredged material may remain in suspension in the water column for some time and be transported elsewhere and interfere with other uses or cause impacts to marine biota.
- *Erodability*; once the material reaches the sea floor it may remain there or be eroded and transported away by water movements and may affect sensitive areas.
- *Shoaling*; may occur due to the piling up of dredged material on the seabed; therefore the site must be deep enough to accommodate this and future dredged material without any adverse effects i.e. upon navigation.

Combining the disposal site requirements related to the dredged material characteristics with the outputs from the first step, identifying potential areas, should result in the identification of one or more potential disposal sites (candidate sites).

3.4.4 Information on Candidate Disposal Sites

Once candidate disposal sites have been selected then information on the physical, chemical, and biological characteristics of both the water column and the seabed at the proposed site/s is required to determine the probable fate and effects of the material to be disposed of. The hydrodynamic conditions at and in the vicinity of the site will determine the transport and fate of the dredged material. The nature and distribution of the biological communities and the proximity of the site to biological resources (such as fisheries) and amenities will define the nature of effects that are to be expected.

Hydrodynamics

To obtain information of currents and tides, consult local tide tables and speak to the local fishermen and other marine users. Simple observations of water currents can be made by simply tossing an object into the water and then timing how long it takes for the object to reach a certain point. The object could be a float, or a sealed bottle partially filled with water or even fruit such as oranges as they float and are highly visible. Place them into the water at the location of the disposal site and see which direction it moves in and how fast it travels from one known point (A) to another (B) where the distance between them is known or can be measured, divide the distance by the time to calculate the water current velocity. A simple way of doing this is by attaching a known length of cord to the object and measuring the time from release to when the cord becomes taught. This method would give an indication of flow direction and speed near the surface and the information could then be used to estimate where plumes from the disposal operation would travel.

It is important to note that currents can be localized, varying greatly over short distances through the influence of tides, winds, river inflow, bottom contours and shoreline configuration. Currents under the water may be different to those on the surface. Water bodies can be stratified due to salinity (halocline) and temperature (thermocline) resulting in density changes (pycnocline) which can alter flows. This will influence where suspended sediment from disposal operations settle out. Therefore observations should also ideally be carried out in mid water and/or at depth.

A relatively simple but effective technique to measure sub-surface currents is to use a sub-surface drogue (Figure 5). This method can give more accurate information on currents and tides as the drogue is not influenced by the wind, unlike floats or bottles on the surface. It can also determine if flows differ at varying depths in the water column. Because they are easily visible the drogues can be tracked by a surveyor on land to determine flow direction and velocities. Figure 5 gives an indication of how to construct a sub-surface drogue. Note that the length between the buoy and the cotton sheet is variable so it can be altered to determine at which depth flows are monitored.

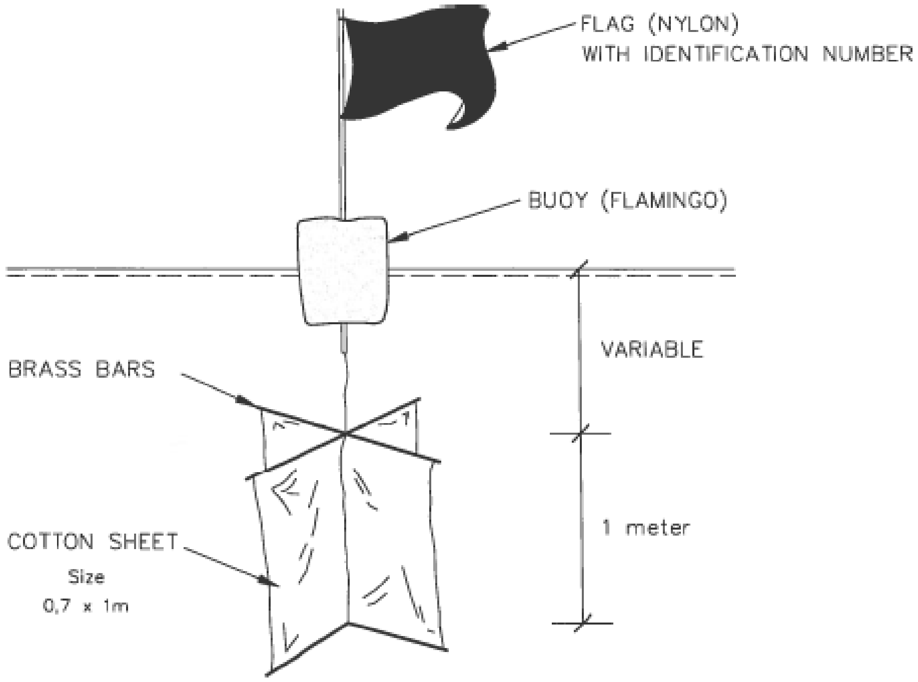

Figure 5. Sketch of a sub-surface drogue.

Near bed flow and sediment transport patterns can be investigated by using seabed drifters (Figure 6) which are released at the disposal site. Each drifter would have an individual number and a label requesting return information and promising a small reward. They are often recovered by, for example, beachcombers or in fishermen's nets. By plotting tracks of returned seabed drifters an indication of near bed flow and residual drift can be gained from which assumptions of the fate of dredged sediment can be made. Drifters can also be weighted to determine/monitor the fate of different particle sizes.

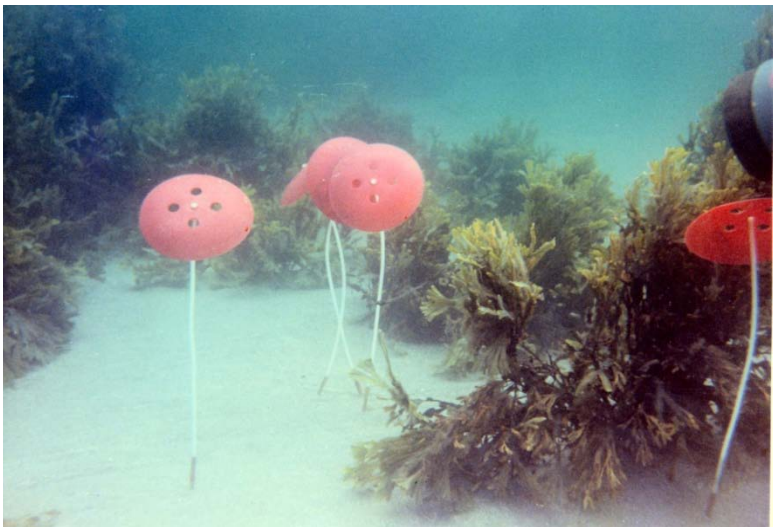

Figure 6. Cefas Mushroom Drifters floating along the seabed.

Wave action is also an important consideration. Disposal sites that are more exposed and subject to strong wave action are more likely to influence the movement of sediments post disposal through resuspension from the seabed.

For further information on the behaviour of sediments after deposition see CEDA & IADC (2008).

Depth
Information may already be available on bottom topography (including seabed depth) through charts and maps. If information is not available and there is no, or limited access, to echo sounders then a simple sounding/lead line could be used to determine the depth of water. All depth measurements were once taken this way and it involves using a line (e.g. piano wire/rope) marked at intervals and weighted at one end which is then lower to the bottom. At more shallow depths divers could be used to gauge depth more accurately.

Generally as depth decreases the more influence waves and currents have which can greatly influence how sediment behaves when it is disposed. For example the likelihood of erosion of sediment once it is at the seabed increases with decreasing depth.

Examining the sediment at a proposed site may give an indication of whether it is a dispersive or non-dispersive site. A site at which fine grain materials were present would indicate that it is likely to be at the non-dispersive end of the spectrum.

Dispersive and non-dispersive disposal sites

Dispersive sites: material is likely to be either be dispersed during deposition or eroded from the bottom over time and transported away from the site by currents and/or wave action.

Non-dispersive sites: most of the material remains on the seabed following deposition in a defined area with little sediment transported out of the site.

There is a spectrum of dispersiveness and disposal sites can be situated anywhere along that spectrum

Size and Capacity
The size and capacity of a disposal site is largely a factor for non-dispersive sites where material will accumulate on the seabed. The site should be large enough to have the bulk of material remain either within a predicted area of impact after disposal. If the site is to receive material over a period it should be large enough take the anticipated volumes. However sites should not be too large as the area of impact will be increased and monitoring may prove difficult, time consuming and expensive.

The following simple calculation can be employed to determine the capacity of a disposal site. Assuming the site is square or rectangular and the size and volume of material is known then the following equation can be used to determine the thickness of material on the seabed.

Thickness = Volume / (length x width)

Therefore, if the disposal site was a square measuring 100 m x 100 m and the volume of material to be disposed was 1000 m^3 then the seabed would be raised by 1 m across the site.

However this assumes an even spread of material across the site and in reality it will be disposed at one or more locations within the site and form one or more mounds. Therefore, Permitting Authorities could employ management measures, such as targeted disposal within a grid system across the site and set a maximum height for mounds to ensure a more even spread of material and prevent interference with navigation.

Biological Resources
Information on the biological resources should be gathered:

1. Within the disposal site - on those resources that will be affected by some degree by being covered with dredged material and
2. Around the disposal site – on those resources that may be affected via sediment transport away from the site.

This could be information relating to fisheries and fishing grounds, shellfisheries, and also sensitive and protected habitats and species. Again stakeholder interaction could prove a valuable source of information; fishermen and divers may have a wealth of knowledge of a site or area of similar bottom characteristics. Specific field work to describe the benthic community at the sites and its surrounds may be required where existing information is inadequate, this is covered in Step 8 Monitoring. Biological surveys by divers or simple boat based surveys would give an indication of the species and habitats present within the potential dump-site and will help inform the likely impacts associated with dumping of dredged material at the site.

Temporal characteristics should be considered to establish if there are certain times of the year when disposal should not take place. This could be in relation to periods when marine organisms are migrating, growing or breeding. An important consideration in regards to the bottom dwelling organisms (benthos) is grain size of the deposited material, generally the more similar the grain size of the dredged material is to the sediment at the disposal site, the more closely the recolonising biota will resemble the surrounding benthic community (CEDA & IADC 2008).

3.4.5 Assess Potential Adverse Effects for Candidate Disposal sites

Each candidate disposal site should be evaluated to determine potential adverse effects of the disposal operations. The evaluations should take into consideration near- and far- field fate of the material and its constituents and short- and long-term effects on marine resources and the environment taking into account the information generated on the characteristics of the dredged material and the disposal sites.

Effects can be grouped into two categories, physical effects and chemical contamination related effects, both of which can occur in the water column and to benthos at the seabed (a summary of potential effects is provided in Figure 7). A low tech approach will generally focus initially on the physical effects and as knowledge, experience and capacity/technology increases this can include chemical related effects. Some of the main effects are outlined below:

Physical effects
Where the deposited material descends rapidly to the seabed it can smother benthic organisms in the disposal site and potentially the surrounding area. This can change community structure and disrupt ecological processes. The deposition of fine grained sediment on coarser grained natural sediment can also change benthic communities and may lead to a reduced biodiversity.

Turbidity and suspended solids can cause deterioration in water quality. Waters with high sediment loads are very obvious because of their "muddy" appearance. An increase in turbidity results in a decrease in the depth that light is able to penetrate the water column. This can result in a reduction in plant photosynthesis which reduces biological productivity (which may impair the food availability in higher trophic levels). Visual predators such as fish and fish eating birds may be hindered as it is more difficult to locate prey. Spawning of marine animals may also be hindered in turbid waters.

Certain biological resources such as coral reefs, shellfish beds, sea grasses and spawning areas are vulnerable to increased levels of suspended solids. For example filter-feeding organisms, such as shellfish, can have their feeding and respiration organs damaged. Corals are especially vulnerable to increased sediment levels because they are only able to survive if the rate of settling of suspended particles is relatively low. (See Step 8, Monitoring).

Turbidity and Suspended Solids

These two water quality parameters are related but not the same.

Turbidity is a description of how clear the water is, or in other words, the degree to which the water contains particles that cause cloudiness or backscattering and the extinction of light.

Suspended solids comprise fine particles of inorganic solids (e.g. clay, silt, sand) and organic solids (e.g. algae, detritus), suspended solids can affect turbidity.

(CEDA & IADC 2008)

It is important to note that turbidity occurs naturally and therefore the effects of turbidity only occur when it is significantly increased above background levels. Effects can be more pronounced in areas not used to receiving large quantities of suspended solids.

A large amount of dredged material present on the seabed and in the water column in suspension can also interfere with fisheries, navigation and, on occasion, recreational activities, e.g. diving and snorkelling. It can also have an aesthetic impact (look bad) which may affect tourism and recreational activities, for example through substances contained with the dredged material like oil or litter floating to the surface.

Contamination related effects

If the dredged material contains elevated levels of contaminants, such as heavy metals or PAHs, organic matter or nutrients then contaminant-related effects may occur.

Heavy metals and organic pollutants can cause toxic effects on organisms when they are exposed to higher than normal levels. Effects can be acute or chronic. Benthic organisms are most susceptible as they live and feed on deposited sediments at disposal sites and surrounding areas. Over time toxic substances can accumulate in marine organisms when they are absorbed or ingested at a greater rate than which the substance is excreted (bioaccumulation).

Dredged sediment with high organic matter content can affect dissolved oxygen in relatively enclosed bodies of water, such as estuaries and coastal embayments. Decomposition of organic matter can deplete dissolved oxygen and if the water column becomes hypoxic or anoxic mass mortalities of marine animals may occur.

Excess amounts of nutrients can cause an increase in algal growth (eutrophication) which can affect water quality and increase the organic matter when the algae dies off.

3.4.6 Evaluate Acceptability of Potential Adverse Effects

An assessment of the acceptability of the potential adverse effects at the candidate site or sites should be made at this stage. Sites with unacceptable impacts can be eliminated from further consideration. If all candidate sites are eliminated, the waste or other material cannot be disposed at sea. If all except one are eliminated, then that site should be used.

Once a disposal-site has been approved for dredged material, then future applications for disposal of the same type of material would normally be suitable for that site, subject to volume considerations.

3.4.7 Compare Candidate Disposal Sites

If two or more suitable and acceptable sites are under consideration, the potential adverse effects of the dredged material at each should be compared.

An approach that can be employed to identify the most suitable site is to produce a comparative table collating information of the potential effects assessment to identify relevant resources and other uses at and in the vicinity of the disposal site. A decision could then be made based on that information, with the chosen site being the one with the least number of potential adverse effects.

However this would not take into account the perceived risk of the disposal operation on the receptors of concern (e.g. relevant resource sources, including habitats and species, or other uses). Risk is a function of the magnitude of an adverse effect and its likelihood. Therefore a conventional risk assessment matrix based on a qualitative evaluation of the perceived risks can be used to inform and provide a consistent approach to decision-making. A good explanation of characterising risk is provided in the LC/LP Assessment Framework for Scientific Research Involving Ocean Fertilization (available on the LC/LP website: http://www5.imo.org/SharePoint/blastDataHelper.asp/data_id%3D30641/AssessmentFramework-Annex6-LC-32-15.pdf).

3.4.8 Disposal Site Selection

When two or more disposal sites appear equally acceptable, then a decision to select a site could be made using other criteria such as economic considerations. This could result in the site closest to the dredged material production site being selected.

3.5 *Step 5: Impact assessment*

Information on Impact Assessment is provided in Chapter 7 'Assessment of Potential Effects' of the generic WAG, it is also discussed in Chapter 6. In the WAG Training Set it is described as a separate step (Part 3, Step 5) because of its importance to several decisions in the process.

3.5.1 Introduction

Impact assessment proceeds by establishing a hypothesis, or prediction, about the potential impact, and then testing it scientifically. In the present context an impact hypothesis is a prediction of the likely environmental impact of a given disposal event at a given disposal site. The purpose of an impact hypothesis is to provide:

- the basis for the decision on whether or not to approve the disposal operation
- the basis for environmental monitoring before and/or after the disposal activity.

Developing impact hypotheses involves:

- identifying potential impacts/effects of specific disposal actions,
- defining hypotheses of what effects may occur,
- deciding what types and levels of impacts are unacceptable,
- drawing up methods for testing the hypotheses,
- verifying the hypotheses, and finally,
- making the decision on whether or not to proceed.

Impact hypotheses may relate to any physical, chemical or biological impacts from the proposed disposal operation at the disposal site. However, they do not cover operational matters such as dredging management. Impact hypotheses predict what may happen following disposal and they also present a means to verify the effects after they occur.

3.5.2 Assessment of Potential Effects

The terms environmental effects and environmental impacts are often used interchangeably; environmental effects are in essence impacts, commonly considered positive or negative.

The assessment of potential effects should integrate information on the characteristics of the dredged material, disposal method and the proposed site conditions. It should comprise a summary of the potential effects on human health, living resources, amenities and other legitimate uses of the sea and should define the nature, temporal and spatial scales and duration of expected impacts based on reasonably conservative assumptions.

The use of a conceptual model to determine the potential impacts is recommended. A conceptual model of the potential impacts of dredged material disposal is provided in Figure 7. This model can be used to identify potential impacts relevant to the proposed disposal activity being assessed. From a low tech perspective not all of the impacts will be easily assessed (e.g. changes in the chemical environment) and not all will be relevant or easily assessed in all cases. However from the information in this training set it should be within the capability of all proponents to make an assessment starting with the physical effects and, as capability increases, a more holistic assessment can be pursued.

All dredged materials have a significant physical impact at the point of disposal. This impact includes covering of the seabed and short-term local increases in suspended solids levels. Physical impacts may also result from the subsequent transport of the finer fractions by wave and tidal action and currents movements. Some of the potential physical impacts will have already been minimized and identified during the site selection process and are discussed, along with chemical-related impacts, in Part 3, Step 4 Disposal Site Selection.

Conceptual Model
The WAG training set promotes the conceptualisation of the range of possible impacts associated with activity through the development of conceptual models.

In essence a conceptual model is a simplified representation of reality; it is a framework for understanding the relationships and processes of an ecosystem and the human activities that affect them. It helps to identify components of the system and interactions that are important in understanding the behaviour of a system as a whole. For disposal activities it can be used in identifying direct and indirect impacts of the activity on the ecosystem and the interaction between impacts.

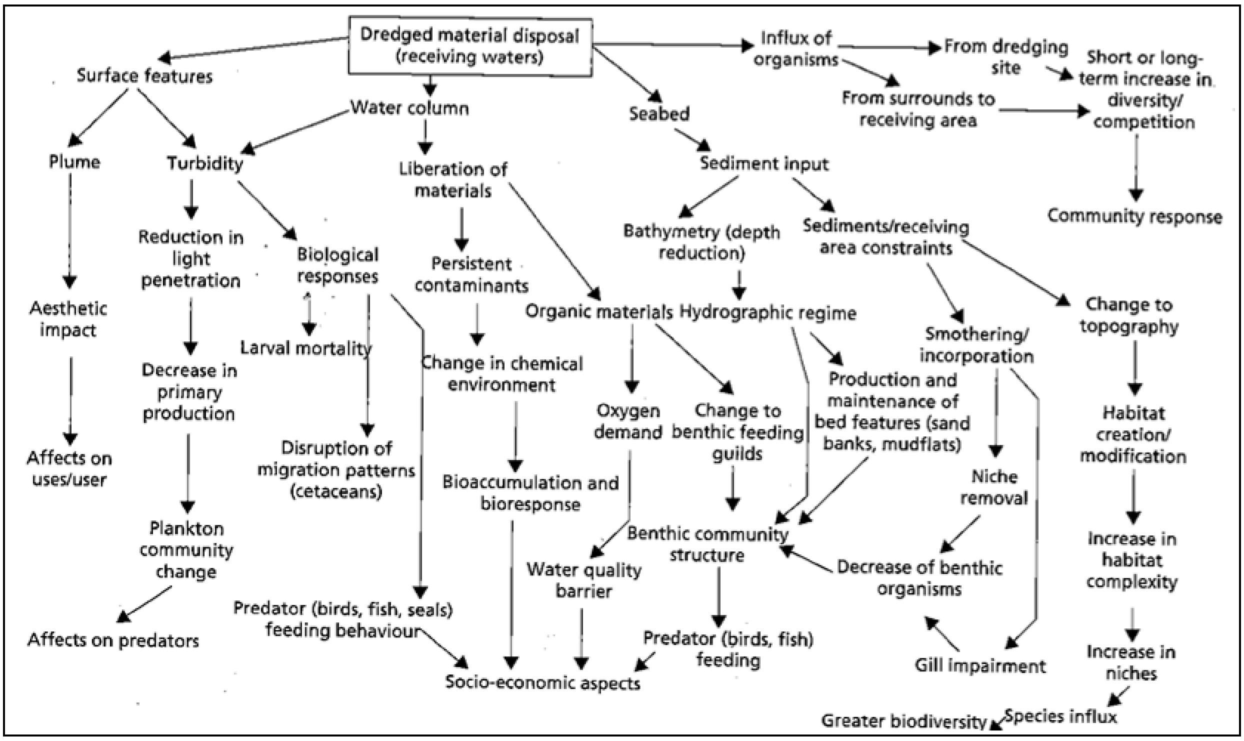

Figure 7. Potential impacts of disposal of dredged material (PIANC, 2006).

The assessment of potential effects involves the investigator making predictions about what will happen to certain receptors following the disposal activity. In order to do that and develop impact hypotheses the investigator requires:

- an understanding of the characteristics of the dredged material (see Step 1 Waste Characteristics)
- an understanding of the characteristics of the environment at the disposal site (see Step 2 Selecting a Disposal Site)
- an understanding of the disposal techniques/methods
- a prediction of the spatial and temporal scales of the impact (See Table 6)
- an assessment of potential effects on amenities (e.g. presence of floatables, litter/oil)

- a consideration of sensitive areas (e.g. spawning, nursery, feeding areas) and other legitimate uses of the sea.

This information should be used to exclude impacts that are impossible or unlikely to determine relevant potential effects taking into account spatial and temporal effects of the dredged material disposal. The definition of spatial and temporal effects and some examples are provided in Table 4 below.

	Near-field environmental effects (<1 kilometre)	**Far-field environmental effects (>1 kilometre)**
Short-term environmental effects (<1 week)	Smothering of organisms. Turbidity /suspended solids. Reduced water quality. Acute chemical toxicity. Reduction of recreational value e.g. swimming, diving.	Offsite movement of chemicals by physical transport. Turbidity /suspended solids
Long-term environmental effects (<1 week)	Altered substrate type Altered community structure Chronic chemical toxicity Bioaccumulation	Offsite movement of chemicals by physical transport and/or biota migration

Table 4. Spatial-temporal matrix of potential effects associated with the disposal of dredged material (adapted from CEDA & IADC 2008)

Once this information has been collated it allows the investigator to ask **IF**...**THEN** questions, for example:

> **IF:** using a hopper dredger you dispose of a defined amount of material which contains a large percentage of fine material but low levels of contamination, at a defined disposal site, which is located in 10 metres of water, close to the mouth of an estuary and subject to strong tidal currents.
>
> **THEN:** a large proportion of the deposited material is unlikely to stay within the designated disposal site and will be transported away from the site in suspension immediately after the disposal activity.

Given the example above, if there were sensitive receptors such as coral reefs or shellfish grounds located close to the site that could be potentially impacted then the investigator could investigate whether there is another site more suited to take this material. If not, are there any mitigation (control) measures that could be employed to reduce the risk, for example dispersion of fine sediment may be controlled by avoiding disposal during spring tides.

Once the environmental effects have been determined the investigator needs to establish which are acceptable and which are unacceptable. It is better to think of environmental effects in terms of acceptable or unacceptable (rather than good or bad). An important point to consider is that most projects will make changes to the environment and that some of the changes may well be adverse, but these adverse changes *per se* do not necessarily constitute an unacceptable impact (CEDA & IADC, 2008). Certain adverse effects may be acceptable in view of the accrued societal benefits.

The most important impacts in the conceptual model are usually risks posed to humans and selected flora and fauna (ecological receptors of concern) and the value of these will influence whether effects are determined to be acceptable or unacceptable. Ecological receptors can be ecosystems, habitats, communities, populations and individual organisms.

Ecological receptor categories include:

- *commercially important*: wildlife, fish, and shellfish populations that constitute economically important resource stock or tourist attractions such as coral reefs,

- *recreationally important*: wildlife, fish, and shellfish populations that are sought for recreational purposes,

- *ecologically important*: flora and fauna populations whose abundance and/or biomass are important to habitat structure, energy flow, or nutrient cycling (such as sea grass beds, kelp forests, and coral reefs), and

- *special status*: individual species whose survival is threatened or endangered.

Once the potential adverse effects have been identified and described and the most important and probable ones determined they can be used to formulate testable hypotheses about possible environmental effects and form the basis of post disposal monitoring.

3.5.3 Preparing and Testing Impact Hypothesis

Defining clear hypotheses can be simple, if you take the standard scientific approach of testing a null-hypothesis (H_0). In summary, the null-hypothesis is that 'there is no difference between x and y'. You then measure various parameters of x and y and use statistics to see if there is a significant difference between x and y. If there is no statistically significant difference, you accept the null-hypothesis and can say 'there really is no difference between x and y, our statistics say so'.

Hypothesis Testing: A simple example.
You may want to know whether the concentration of chemical X at a disposal site is similar or different to that of the dredged material. You construct the null-hypothesis that '*There is no difference in the concentration of chemical X between the disposal site and the dredged material*'. You then measure the concentration of chemical X in a number of samples from the disposal site, and find the mean and standard deviation. You do the same for samples from the dredged material.

Using an appropriate statistical test to compare the data from the disposal site and the dredged material you can see if there is a statistically significant difference. If there is not, then you accept the null hypothesis. If there is, then you can set up and test an alternative hypothesis, such as '*The concentration of chemical X is greater in the dredged material than at the disposal site*' and test this.

If there are several potentially unacceptable impacts, then more than one testable hypothesis may be required. It is important to ensure that the hypotheses that are derived are realistic in terms of: (1) the availability of resources to test them and (2) their cost effectiveness, relative to the proposed disposal activity.

Testing certain hypotheses may require field surveys to establish baseline information in order to distinguish between natural variability (spatial and temporal) and any effects caused by the activity itself. This would be relevant in order to test for effects on biota, for example through assessing community parameters such as species richness (number of species) and composition, assessing numbers of a specific organism, or through taking sediment samples for bioassays.

Examples of impact hypotheses:

- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis.

- The wider dispersal of fine particulates arising from sediment disposal, including any bedload transport, will have no unacceptable adverse consequences for the marine biota or for recreational/amenity interests.

- During the initial disposal, amounts of dredged material carried in suspension in the water column to any sensitive area will not have harmful effects on biota in those areas

An hypothesis should be tested against pre agreed objectives and standards, which should be quantitative, where possible. These can be based on knowledge of baseline conditions, which can be derived from pre-disposal monitoring, information from the disposal site characterisation or local knowledge of the area. The hypotheses should also be suitable to guide monitoring. An example is provided below in Table 5.

Hypothesis (H_0)	**Hypothesis is rejected if:**	**Associated monitoring**
Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis	At sample stations >1 km from the disposal site, along the tidal axis, the amount of fine sediment is 20% greater than compared to the pre-disposal baseline and reference sites	Sediment samples taken at relevant stations pre and post disposal activity and analysed to determine physical characteristics.

Table 5. Example of a null hypothesis, criteria for rejection and associated monitoring.

3.5.4 Permit Decision

The assessment should conclude with a decision on whether or not to allow the disposal activity to proceed. This decision should be based on all the information gathered in this and the previous Steps 1-5, and the defined hypothesis.

If the project is found to be acceptable and approved then the assessment proceeds to Step 7 Permit Conditions. If the impacts are found to be unacceptable and the project is likely to be rejected then the permitting authority may refer the project back to the applicant. The applicant may then decide if the project can be reformulated, based on feedback from the assessment, to reduce the impacts to acceptable levels.

3.6 Step 6: Permitting system

Guidance on permitting systems can also be found in Part 3, Step 6 of the WAG Training Set and in Chapter 9 of the Waste Specific Guidelines.

3.6.1 Introduction

A permitting process is the means by which ocean disposal is controlled by authorities appointed by national governments and is therefore the core of both the LC and LP. Information is requested for evaluation, requirements for reporting and monitoring are set out, and enforcement is conducted to ensure that the process is effective.

Whether at the planning stage or early in the development of measures to manage ocean dumping it will be useful for countries new to these approaches to think in terms of how operations could be permitted (even if a permitting system is not currently in place) and apply these principles as this will help to devise a usable framework. A permitting system may evolve from the best practice principles outlined in Part 3, Step 6 of the WAG Training Set.

In addition, in advance of any legislation setting up a system to manage ocean dumping, it is possible to setup an informal or voluntary system with the agreement of relevant port, harbour and other bodies requiring dredging and disposal, as well as other relevant national agencies. Such a system operated in the UK for some years prior to the Dumping at Sea Act being enacted in 1974 and coming into force the following year.

Both the LC and LP call upon Contracting Parties to protect and preserve the marine environment from all sources of pollution and, in particular, to prohibit unpermitted dumping at sea, to establish a permit system, to report the activity to the meeting of parties, and to monitor the impacts of dumping activities. Part 3, Step 6 of the WAG TS will help countries to explore this concept and set the foundations for a permitting system. A well-conceived permitting system, supported by law, wherever possible, will enable a party to meet these responsibilities and commitments.

Article 4 of the LP states that:
"Contracting Parties shall adopt administrative or legislative measures to ensure that issuance of permits and permit conditions comply with the provisions of Annex II."

Although it is possible for a permit system to run on administrative measures, some form of legislation may be helpful to support or embody the permit system.

3.6.2 Considerations in Establishing a Permitting System

The Parties to the LC/LP have developed guidance that can help a party put in place the legislative or administrative measures that will fulfil the obligations of a Party that is seeking to ratify or accede to the LP. To obtain these guidelines, contact the Office for the London Convention and London Protocol, or access the LC/LP website: http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx. New or prospective Parties may also call upon States that are already party to the Protocol for advice, technology transfer, or examples of legislation in place to control dumping at sea.

The WAG TS identifies the following major elements of a permit system:

- required prohibitions;
- designation of a national authority to administer the permitting system and report;

- enforcement capability; and
- monitoring.

3.6.3 Additional Considerations

Check if other sea pollution conventions or commitments such as MARPOL, UNCLOS, or GPA are being implemented in your country and who is responsible for their implementation. It will be worth exploring the possibility of co-ordinating efforts as these agreements cover complementary aspects of marine pollution prevention and protection. Shared administration, or enforcement with other authorities could provide efficiencies and avoid potential conflicts or duplication.

Regional seas conventions (such as OSPAR, HELCOM, Barcelona, and Nairobi Conventions) support marine pollution issues specific to regional seas and may include dumping at sea. National government pollution prevention goals and laws relating to marine, freshwater, and land-based activities should also be considered for the same reasons as above.

3.6.4 Permitting Authorities

Under the LP, permit systems are applied by authorities appointed by national governments and therefore the permitting authorities are usually federal or national. Due to the nature of the permit assessment those authorities are generally from environmental, navigation and/or transport departments. However, in countries where these authorities are not in place or readily identified, individuals or bodies are encouraged to implement a simple permit system to assess and manage dredged material even if this is initially at a local level.

Those undertaking permit issuance (referred to as authority hereafter) would need to be able to assess the suitability of dredged material for sea disposal, issue permits, keep records and monitor operations. This would require the following:

- Staff with the necessary knowledge and expertise to assess applications.
- Administrative support for issuance of permits, record keeping etc.
- Staff to enforce the regulations,

A review of the potential number of disposal operations within the jurisdiction of the permit system would give an indication of resource needed. Check to see if other agencies, which may already have a enforcement remit, could undertake the enforcement of the regulations/permits. This could save resources and that agency may also have recognised authority with the applicants if the enforcement agency/officers are already known.

Consideration must also be given to training staff to undertake the roles outlined above. Information would also need to be made available to applicants as to how the permit process works and what information they would need to supply with an application to obtain a permit.

3.6.5 Consultation Networks

A consultation network can be established to provide additional expertise and local knowledge into the assessment that may not be available within the permitting authority. This can ensure a more robust assessment process, in particular identifying any conflicts that may occur with other users early on. This approach can also promote understanding of the activity and its regulation, and may help identify alternative uses for the material.

Consultation can take place with anyone the permitting authority feels is relevant to the process. This can include agencies (governmental and NGOs), users, interest groups and individuals, some of those may be already known. To ensure all relevant bodies are consulted a suggested approach is to undertake a review of those involved, or with a stake in, the interests below. Then send out information to them detailing the regulations/permit and the activities involved asking if they have an interest in being consulted. Interests can include:

- Environmental and conservation: government agencies, conservation bodies or conservation groups, all of whom could have knowledge of areas of scientific or conservation importance

- Fisheries (shellfish and fin fish): through consultation with relevant agencies which may have responsibilities for protecting fisheries, fishing organisations, aquaculture operations, or fishers local to the area.

- Navigation: coastal protection authorities, port authorities, ports, marinas, yachting organisations.

- Leisure: water sports organisations and groups e.g. diving and sailing, recreational angling.

Countries who are party to the LC/LP may also be a source of assistance and advice to those setting up a permitting system. In addition, the London Convention and Protocol has a Technical Cooperation and Assistance programme to assist both existing and potential Contracting Parties. This could be in the form of general advice on processes to more technical advice on specific applications.

3.6.6 User Pay

One of the principles of the LP is that users should bear the costs of meeting the pollution prevention and control requirements for authorized activities, with due regard to public interest.

Consider if it is in the public interest or national purview for fees to be charged for assessment, collecting information and monitoring activities. Permit fees could offset the costs of the whole programme or just part of it, e.g. administration costs. However it is important to ensure the market can bear those costs and that the fees would not promote illegal dumping.

3.6.7 Establishing the Permit Process

Essential to the permitting process is establishing systems that collect and maintain relevant information needed to assess the suitability of dredged material for sea disposal and the issue of permits. It is also worth considering at the outset how to maintain information over the long term which can aid reporting and also reviews of processes to improve waste assessment. Authorities must also consider that once the process is in place, if it has legal authority, then enforcement activities may be necessary. Therefore, it is advisable to consult relevant experts to ensure the system meets the necessary requirements for legal proceedings.

Authorities need to develop a standard list of questions to ensure that they get the relevant information from applicants to assist the assessment. Basic practical information will be required on the following:

- Where the dredged material will come from;
- What is known about the material, what volume will be disposed, has it been characterised before;

- Has material from the area has been disposed at sea previously, if so, when and from where to where;
- When the disposal is planned to take place;
- How the dredged material is to be disposed (equipment);
- What other uses of the sea are there in the locality that may cause conflict with the disposal activity

This information will aid the assessment process and can also be used as the basis to build the permit itself, this is discussed further in Step 7.

The authority will usually be responsible for the establishment of the permit system. However the collection and submission of the required information to support an application is usually the responsibility of the applicant. It is recommended that authorities considering, or are in the process of, establishing a permit system engage with industry and potential applicants at an early stage in the process. This will ensure that applicants are aware of what information and detail is required to support an application and also enable the authority to gauge the capacity of applicants to provide that information. Written guidance should be produced and available to potential applicant. , It may also prove valuable to offer a pre-submission consultation to ensure the relevant information is provided. This may save time asking the applicant for further information during the assessment process.

Once the application has been received the authority will review the information to ensure it is adequate and of the required quality. If a consultation network has been established then it can be employed to review and verify the information and raise any concerns or questions regarding the activity.

The authority will consider the results of the characterisation of the waste or other matter, the dump-site selected, the results of evaluation of alternatives, and whether any potential conflicts with other legitimate uses of the sea can be determined.

If a permit is to be issued then permit conditions, restrictions and limitations may then be defined (See Step 7 on Permit conditions). In granting a permit the responsible authority is accepting the hypothesised impacts that may occur as a result of the activity. Permits should be issued in advance of the disposal activity.

Permittees should be required to report back to the authority on the dates and quantities disposed under their permits. The authority should record this information so that it can be used to review and manage disposal at sea operations more effectively into the future. It will also be useful to establish this process for those authorities/countries aspiring to be signatories to the LC/LP as information on disposal activities is a reporting requirement.

3.7 Step 7: Permit conditions

Guidance on permitting conditions can also be found in Part 3, Step 7 of the WAG Training Set and in Chapter 9 of the Waste Specific Guidelines.

3.7.1 Introduction

The permitting authority should only issue a permit for a disposal operation once the proposed project has been thoroughly evaluated. The permitting process ensures that only dredged material that has been properly assessed is disposed at sea at the location (disposal site) identified where impacts are acceptable and monitoring can occur.

In issuing a permit the permitting authority is accepting the hypothesised impact that will occur at the disposal site, such as alterations to the local physical, chemical and biological environment. The permit is an important tool for dredged material management and will contain conditions under which the activity may take place. Put simply, the permit and its conditions state that the permit holder is allowed to undertake X (the disposal activity) as long as they do Y (adhere to the conditions). Therefore it is important that the permit conditions define the limits of the activity whilst ensuring that, as far as practicable, the environmental disturbance and detriment are minimised and benefits maximised.

In drafting conditions it is important to take into account the technology and equipment available, for example, there is no point in the permitting authority asking for detailed bathymetric survey of the disposal site when the technology is not available to the permit holder. In addition social and political concerns may need to be taken into account.

Permit conditions can also provide the means to obtain the information used in national and global tracking and reporting as required under the LC/LP. Those permitting authorities from countries not yet party to the LC/LP should still endeavour to obtain this type of information to inform the evaluation of future activities so that regular reporting is well established for countries aspiring to be party to the LC/LP.

Permit conditions can serve several purposes, including requirements for information for:

- basic administration information,
- environmental protection,
- actions necessary to assure compliance,
- environmental restoration, and
- monitoring or reporting.

Any permit authorising dumping will need, at the very least, to contain data and information specifying the following:

- types, amounts and sources of material to be disposed,
- location of the disposal site,
- method of disposal, and
- monitoring and reporting requirements.

The basic purposes of permit conditions are introduced in the following section and sample conditions relevant to dredged material disposal activities are provided.

3.7.2 Types of conditions

Administrative Conditions

These conditions specify the basic elements and requirements of the permit. For dumping permits these can simply include who, what, when, where and how:

- *Who* is authorised to undertake the disposal.
- *What* can be disposed, the type and source of material.
- *When* the disposal is allowed to take place.
- *Where* the material is to be disposed, the name and location of the dump-site.
- *How* much material can be dumped, the allowable volume.

Administrative conditions may also specify: the right of the permitting authority to undertake inspection of the activity; when permit fees are to be paid, if they are required; if and how the permit holder is required to inform other users, such as local fishermen, of when and where the dumping activity is to take place and; whether permits are required to be posted at the site of works and on vessels involved in the dumping operation. Example condition:

> *"The licence holder must ensure that the material is evenly distributed across the dump-site."*

Environmental Protection Conditions

Environmental protection conditions ensure that the required environmental safeguards are put in place. They should be based on the issues determined during the disposal site selection process (see Step 4; Selecting a disposal site) and/or the impact assessment of the potential effects of the disposal activity (see Step 5 impact assessment). These can include timing restrictions, such as calendar restrictions to protect other resource users (migrating and spawning fish species) or restrictions on disposal to certain periods of the day or tidal cycle, which can, for example, limit the suspended sediments effecting shellfish beds or reefs. Example condition:

> *"No dumping shall take place from March 1st – July 31st in order to minimise adverse impacts to migrating fish species."*

Compliance Conditions

These conditions set out what the permit holder is required to do to demonstrate that they are in compliance with the permit. They can include the requirement for the permit holder to provide reports of each dumping event. This may include details of the timing of the activity, location and amount disposed. If certain technology is available then conditions can be set accordingly, for example, the requirement for an electronic tracking system which can report on the exact movements of the vessel and dumping locations. If technology is not available, then the permitting authority could simply set conditions to monitor compliance by observers or inspectors present on the dumping vessel to witness and report on dumping activities. Example condition:

> *"The permit holder must ensure that all dumping activities carried out under this permit are witnessed by an onboard observer who has been appointed by the permitting authority."*

Monitoring Conditions

Monitoring during and/or after the disposal operations can provide information to ensure compliance or to make management decisions. For compliance needs, conditions can stipulate what information is required to answer compliance type questions such as, where, at what levels and for what duration.

Monitoring conditions may be required to map the distribution of material on the seafloor, determine changes in water depth, assess biological recovery and assess contamination of sediments within or outside the dumping site. It is important that the monitoring conditions set are realistic to the resources or technology available and that they relate to information needed to make management decisions.

Monitoring requirements may also be designed to provide 'performance type' requirements that can change the permittee's obligations based on the results of monitoring. This is done with an 'if- then-do or do-not-do' type condition'. For example if water depth below a specified depth is a potential navigation hazard then the permittee could be required to dump the material evenly over the dump-site. This could be achieved by dividing the dump-site into sub-sections (i.e. a grid system). The permittee is then allowed to dispose material into one of the sub-sections and is required to measure (sound) the dumping point depth regularly during the disposal operation. If at any time the depth is less than the specification, the permittee must stop dumping at that sub-section and move onto the next. Example condition:

> *"The permittee must ensure that during the course of disposal, material is distributed evenly over the disposal site and ensure that no depths within the disposal site are reduced to less than 7.0m below Admiralty Chart datum. "*

Environmental Compensation Conditions

This type of condition can detail the requirement for any mitigation actions if a dumping operation is to result in a loss of resource. Following the site selection process (see Step 4 Disposal site monitoring) should remove the need for mitigation action, however, on occasions, resources may be affected if no other suitable site can be identified. This occurred on the East Coast of UK when a dumping operation was to result in impacts to lobster habitat in an area where lobsters were commercially fished. The permittee was required to cover part of the dump site with a layer of gravel to make it similar to the habitat affected and suitable for lobsters to colonise. Example condition:

> *"The permit holder will ensure that on completion of disposal activities gravel will be sprinkled over the deposited material on the western side of the dumping site with the aim of enhancing the suitability of the habitat for colonisation by commercial shellfish."*

Reporting conditions

The permitting authority may also set conditions that ensure the permit holder provides a report (or reports) on specified aspects of the activity. This could include, for example, information of the actual disposal activities, compliance results and post-operation monitoring. The condition would need to set out what was required in the reports and to whom and when they should be submitted. Example condition:

> *"The permit holder shall submit a written report to the permitting authority within 20 days of completion of the works. The report must contain details of the amount (in tonnes), location and timing of each disposal event."*

3.7.3 Drafting Permit Conditions

Permit conditions should be clear and drafted in plain unambiguous language. They must clearly state who needs to do what, when, where and for how long. Often permit conditions state the purpose of the condition so the permittee can understand why it has been set (i.e. no dumping allowed at a certain times to minimize impacts to shellfish resources). The use of language like 'shall' and 'must' is recommended as it implies that the permit holder is commanded or compelled to do something. The use of vague language in permits can lead to misunderstandings between the permit authority and permit holder which if the case becomes subject to enforcement action because of non-compliance can be used as a defence against prosecution.

Further information on preparing permit conditions including the language of permits and prescriptive and performance-based conditions is provided in Part 3, Step 7 of the WAG Training Set.

3.8 Step 8: Monitoring

Guidance on monitoring can also be found in part 8, Step 4 of the WAG Training Set and in Chapter 8 of the Waste Specific Guidelines.

3.8.1 Introduction

Monitoring is used to verify that the permit conditions are met and the assumptions made during assessment of the project are correct. Monitoring programmes need to have clear objectives that can be tested in a practical way.

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3.8.2 Types of monitoring

Types of Monitoring

- **Compliance Monitoring** makes sure that the permit conditions are met. For example, what time of the day and in what season dredging can take place.

- **Field Monitoring** is done to make sure that the assumptions made during review of the permit and selection of the disposal site are correct and good enough to protect the environment and human health. For example, is there a plume, how big is it, which direction does it go and is it affecting anything important?

3.8.3 Design of the Compliance Monitoring Programme

List the Permit Conditions and identify which ones must be verified during dredging and disposal. Each of these Conditions should be measurable, for example, is the operation to take place at a particular time of the year, on a specific date; usually dredging is to be done only in one place and the dredged materials are to be disposed of at one site. All this type of information will form Conditions of the Permit that should be monitored to see that they are taking place the way the Permitting Authority requires.

3.8.4 Design of the Field Monitoring Programme

Field Monitoring can also go by the name of Impact Monitoring or Surveillance Monitoring and is designed to see if assumptions made during assessment of the project are correct. There are very complex approaches to measuring these things but most assumptions can be verified almost completely by direct observation by a knowledgeable person. Direct observation can be supplemented by use of divers using still or video cameras.

Direct observation by a knowledgeable person can provide considerable useful information on whether the assumptions made during the assessment of the project are correct. It is important not to take measurements that cannot be understood, for example, taking multiple water samples does not necessarily help to understand where a plume from a disposal site is going, especially if direct observation is possible to ensure that the measurements make sense. Documentation with a still or video camera may be more useful than water sampling in some situations.

3.8.5 **Who undertakes the monitoring**?

Both field and compliance monitoring can be done by the permitting authority, or by a body appointed on behalf of the permitting authority. The permitting authority may also direct the permittee, the one who is doing the project, to do certain monitoring activities and make these conditions of the permit.

3.8.5 Low Tech Monitoring Methods

Some examples of low tech monitoring methods that could easily be employed in a monitoring programme are outlined below.

3.8.6 Simple Observations

To monitor compliance with permits simple observations can be made from the shore or from vessels to monitor the disposal activity. These observations can ensure that disposal is taking place in the right location and at the appropriate time, if stipulated. Observations can be documented by taking photographs or video of the operation.

Shore-based observations can be used to record the start and finish time of vessels, the direction of travel and if relatively close to shore when the material is deposited; vessels will be lower in the water when carrying their cargo of dredged material. Equally observations from other vessels can provide this information and can be used if the disposal site is farther off shore.

Once the dredged material has been disposed then, depending on the material and site conditions, there may well be a plume. Observations of the plume can confirm predictions made about the direction of the plume, where it is expected to travel. This may be relevant if there are sensitive areas near the disposal site. For example, the disposal activity may have been restricted to a certain state of the tide to avoid suspended sediments impacting sensitive areas.

Observers could also be put on board the disposal vessel. The permitting authorities may appoint a person to ensure activities are being carried out in accordance with the permit and include this being carried on a vessel as a permit condition.

3.8.7 Plume monitoring

Information on the extent and nature of suspended-sediment plumes generated by dredge and disposal activities is necessary to understand technical issues including sediment transport and associated environmental concerns. During dredging projects, Permit Conditions commonly require that methods are put in place to monitor operations and ensure that the suspended sediment levels do not exceed pre-defined ranges. From a low tech perspective, plume monitoring can be employed to identify when an excessive amount of suspended solids are released into the water column as a result of disposal activities. With more advanced monitoring techniques, information is often real time and can feed back and slow down or cease dredge operations until suspended solids reach an acceptable level. Visual observation of the plume reaching a sensitive shellfish bed could result in a change in timing or placement of disposal.

Most dredge plume monitoring efforts focus on monitoring total suspended solids (TSS) and/or turbidity associated with the dredge plume. TSS is a measure of the total mass of material in a given volume of water and is measured in milligrams/litre (mg/L). The majority of studies conducted on the impact of sediment plumes on the environment focus on TSS. Turbidity, a measure of the light-scattering properties of a volume of water, is also related to the type and quantity of particles suspended in the water. Turbidity is defined as cloudiness or haziness of a fluid caused by individual particles, or suspended solids (see Step 4, Selecting a disposal site). Turbidity measurements are often used to monitor the TSS in the water.

It is relatively difficult and often cost-prohibitive to directly measure TSS; therefore turbidity measurements are often used for monitoring suspended sediment in the field as a substitute for TSS. Turbidity measurements are reported in nephelometric turbidity units (NTU) or Jackson turbidity units (JTU). Different units are used depending on which method is chosen to measure turbidity. The two units are roughly equivalent and can be used interchangeably for field purposes.

Low-tech methods can be used to derive a relatively inexpensive general picture about turbidity. Collecting a sample of water to be tested, especially from a particular depth within the plume, is important. The following method is one approach.

Cola Water Sampler

The Cola Water Sampler consists of a cola bottle in concrete (Figure 8). The concrete increases the weight of the sampler. The stopper is made of cork and fastens to the bottle with rope. The rope is held in the hand and you can release the stopper by tugging the rope.

Figure 8. Cola Water Sample in the locked position and once released.

Table 6 below provides a number of low tech methods than can be used and details their strengths and weaknesses (adapted from Myre and Shaw 2006).

Method	Advantages	Disadvantages
Naked eye - Water poured in tube	Fast Cheap	Inaccurate, rather indicative Steps 20NTU/200NTU/2000NTU
Jackson Candle Turbidimeter - Water poured into tube. - Reading taken when candle burning under tube can no longer be seen.	Historical method	No longer a standard method. Can't measure < 25 JTU (25 NTU).
Siltation percentage - Water poured in container - Height of sediment relative to tube length	Indicative, Cheap Define settlement time No consumables	Time Can't measure NTU
Secchi Disk - Black and white disk lowered into water. - Maximum distance at which disk can be seen recorded.	Low cost. Portable. No consumables. Easy to learn.	Less accurate. Can't be used in shallow water or swift currents. Not applicable to small sample size. More suitable for shallow water
Turbidity Tube (Transparency Tube) - Combination of Jackson candle and Secchi disk methods.	Low cost. Portable. No consumables. Easy to learn. Suitable for all water sources.	Less accurate. Can't measure < 5 NTU.

Table 6. Summary of low tech turbidity methods

***Naked eye* -** With the naked eye, an average person can begin to see turbidity levels starting at around 5 NTU and greater. If water appears muddy, its turbidity has reached at least 100 NTU. At 2,000 NTU, water is completely opaque (Joyce, 1996). The type of particles present in water can often be estimated by inspection. Organic particles such as algae give a greenish-brown colour to water. Colloidal particles look like a very fine suspension (Oxfam, 2001).

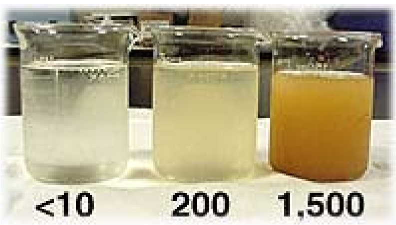


Figure 9. Turbidity of <10 NTU, 200 NTU and 1,500 NTU.

***Jackson Candle Turbidimeter* –** This consists of a flat-bottomed glass tube that sits over a candle (Figure 10). A water sample is poured into the tube until the visual image of the candle flame diffuses into a uniform glow. The depth of the sample corresponds to a certain number of Jackson turbidity units, or JTUs.

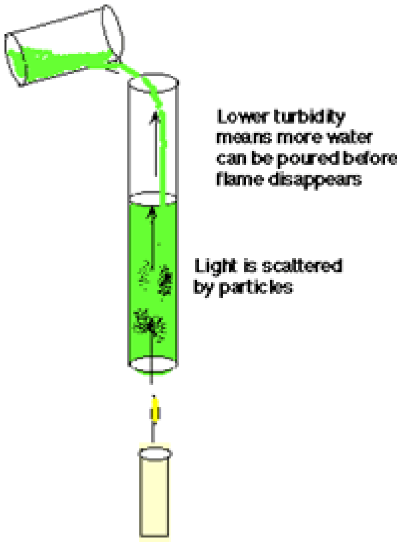


Figure 10. A Jackson Candle Turbidimeter

The Jackson Turbidimeter does have some practical limitations because it cannot measure turbidity lower than about 25 JTU and depends on human interpretation. In addition, the candle flame is in the yellow-red part of the spectrum which is not scattered effectively by small particles.

***Siltation percentage* -** The percentage of fines present in a sample of set volume based on a relative length measurement of the settled silt after 6 h, 12 h, 24 h and 48 h in a clear tube or bottle with fixed length indications (Figure 11). Silt percentage equals the height of the silt in the tube, at a specific time, divided by the total length of the tube, multiplied by 100. Although this method is rather inaccurate it will give a good first indication of the amount of fines in a solution and the time it takes to settle under perfect laboratory conditions.

Figure 11. A simple way of measuring percentage of fines.

***Secchi Disk* -** A Secchi disk (Figure 12) is a device typically used to measure the turbidity of larger bodies of water. A simple weighted disk is used and the water depth at which the disk just disappears from view as it is lowered into the water is measured —the Secchi depth. It has an advantage over the first two methods as it can be used to determine an estimate of turbidity in the field before or while disposal is taking place. This uses the same principle as a turbidity tube, but instead of pouring the water over the disk as in a turbidity tube and measuring the height of non-visibility, the Secchi disk is lowered below the surface to the depth of non-visibility.

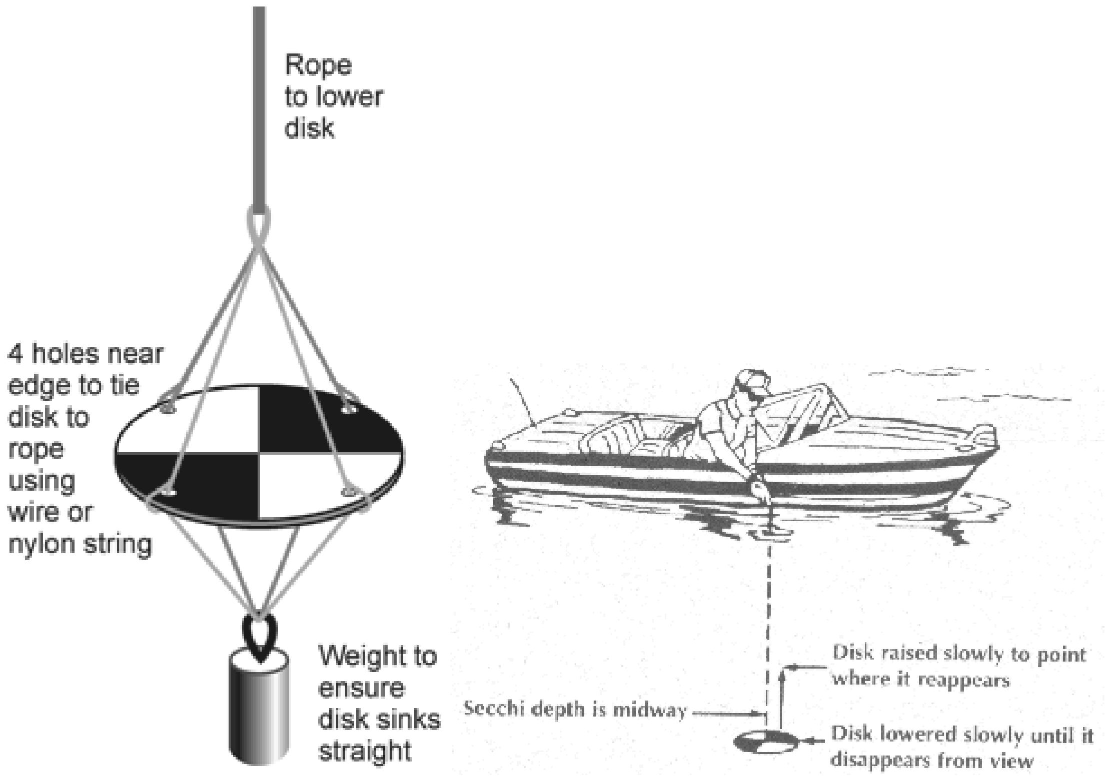


Figure 12. A Secchi disk and it being deployed from a small boat.

The clearer the water, the greater the distance before the disc is no longer visible. Clear, clean water may have Secchi depths of more than 30-40 m, while in some turbid waters (plumes) the depth may be 1 m or less. A Secchi disk is a simple piece of equipment and is relatively easy to make. They are extensively used in volunteer monitoring programs, such as the US Environmental Protection Agency (EPA) Volunteer Estuaries Monitoring Programme.

Further information on how to construct and use Secchi disks and also turbidity tubes can be found in Ohrel & Register (2006) and on the EPA website:
http://water.epa.gov/type/oceb/nep/monitor_index.cfm

***Turbidity Tube* -** The turbidity tube (sometimes called a "transparency tube") is a clear, narrow plastic tube marked in units (usually centimeters) with a light and dark pattern painted on the bottom. Water is poured into the tube until the pattern disappears. Appendix 1 provides details on how to construct and use a turbidity tube.

3.8.9 Sedimentation monitoring

A simple way to monitor sedimentation would be to use divers to survey relevant areas before and after disposal operations to observe if there has been any increase in sedimentation. A more common method is to use sediment traps.

Sediment traps are instruments used to measure the quantity of sinking particulate organic and inorganic material in the aquatic environment. Sediment traps normally consist of an upward-facing funnel that directs sinking marine suspended solids towards a mechanism for collection and preservation. Typically, traps operate over an extended period of time (weeks to months) and record the changes in sinking flux with time. Traps are often moored at a specific depth in the water column in a particular location, but some are so-called Lagrangian traps that drift with the surrounding ocean currents (though they may remain at a fixed depth).

Changes in particle size can be monitored using a stationary sediment trap such as a "Booner" tube (Figure 13). These can be mounted on scientific instrument packages, piers, groynes or other structures for various periods depending on the sediment regime. Potential uses include monitoring of sedimentation rates and impacts of sediment plumes on sensitive species; inundation studies and changes to the organic content. For further information on sediments traps see Grasshoff *et al*. (1999).

Figure 13. A Booner sediment trap (circled) mounted on a Cefas Seabed lander (MiniLander) and the design of a sediment trap.

3.8.10 Biological monitoring

At a designated disposal site, the material is placed at the seafloor. Therefore it is opportune to monitor the sediment and status of the organisms living directly on the seabed. Benthic communities are especially suited for comparative investigations since many of the constituent species are sessile or have low mobility, are relatively long lived and integrate effects of environmental change over time (e.g. dredged material disposal). Several simple approaches for a basic evaluation of the benthic community, such as total number of species, total abundance and the presence of key indicator species, can all provide useful information on the sediment condition.

Pohle & Thomas (*undated*) provide recommendations and guidelines for sampling, sample processing and data analysis of marine benthos. One of the most frequently used methods is grab sampling.

Grab sampling - Monitoring can be employed to determine effects on species or communities both within and outside the disposal site. Traditional sampling tools (e.g. grabs) can be used to obtain samples from which sediments and their associated benthic fauna can be quantified (macrofauna) (e.g. Boyd, 2002; Eleftheriou and McIntyre, 2005). An outline of the steps involved in taking and processing sediment samples for biological monitoring is provided below:

> ***Sampling*** - Grab samplers need to be deployed from vessels and lowered vertically to the seafloor. On reaching the seabed the jaws of the grab 'bite' out a volume of

sediment. Corers can also be used but in contrast to grabs consist of tubes which penetrate the deposit and thus retain a plug of sediment.

There are numerous types of grabs being used for benthic sampling. Eleftheriou & Holme (2005) provide a review of different types. A choice of grab type should first be determined by requirements related to a particular monitoring study. This can depend on the working conditions and the particular environment under which the gear is being operated. Sometimes the size of the desired sample, cost, simplicity, and ease of use are also determining factors. The Day grab is widely used and has the advantage of simpler and safer construction relative to other equipment such as the Hamon grab.

Figure 14. A simple hand held grab

Initial handling - unloading of the grab. The condition of the sample needs to be ascertained and recorded before emptying the contents into a container. Samples can be emptied into appropriately marked or labelled buckets until further processing is possible.

Sieving of the samples - Benthic samples need to be sieved to separate the animals from the sediment. Sieves/screens are made from stainless steel, bronze or brass gauze attached to the bottom of a sturdy frame 15-25 cm high. The size of the holes in the sieve will greatly affect the numbers and types of animals retained. Using a 5 mm mesh sieve will retain larger individual animals, 1 mm mesh can also be used but this would retain more animals and take longer to process. Organisms are removed and transferred to plastic bottles or buckets (depending on the size of the sample).

Processing – samples can be processed immediately, however, mostly they are fixed with a preservative so they can be sorted later. Samples can be fixated with a formaldehyde preservative solution, sometimes with Rose Bengal stain added to enable easy identification of organisms (it makes the organisms colour pink which aids the sorting from the remaining sediment and detritus in a sample). Samples should be appropriately labelled with relevant information to identify when and where samples were taken.

Sorting – the sorting is generally done using a microscope and fine stainless steel forceps. A small amount of the sample to be sorted is processed initially for ease of identification of the organisms. This process is repeated until the entire sample has been completely sorted. The data are recorded. The identification of the organisms would require a suitably experienced/qualified person.

Analysis – the data should be analysed statistically to determine if there are any significant changes in the benthic communities at the monitoring sites (both potentially impacted and reference stations) before and after the disposal operations.

Diver surveys - Monitoring of marine organisms can be undertaken by divers in areas where monitoring sites are shallow enough for divers to be able to reach the seabed for suitable lengths of time. Some habitats such as sub-tidal rocky areas and ecologically sensitive areas (such as coral reefs or seagrass beds) do not lend themselves to being monitoring using grab samples as described above). Often these types of environments are more sensitive than soft sediments to some potential impacts (e.g. siltation). Therefore to obtain data divers can be used to survey these areas and undertake visual observations of the sediment type and species that they encounter.

3.8.11 Sediment monitoring

Sediment can be monitored to establish if there is a change in sediment type as a result of the disposal activity. This can determine whether the zone of impact and the extent of change outside the zone of impact differ from those predicted.

Sediment can be obtained and analysed from grab samples taken for biological monitoring; they can also be taken relatively easily using small hand held grabs (Figure 10) which can be deployed from a small boat or even over the side of a quay or jetty.

The sediment can then be analysed for its physical and chemical composition as outlined in Step 1 Waste Characterisation.

3.8.12 Feedback

Information gained from field monitoring, (or other related research studies) can be used to:

- modify or terminate the field monitoring programme;
- modify or revoke the permit; and
- refine the basis on which applications to dispose dredged material at sea are assessed.

Concise statements of monitoring activities should be prepared. Reports should detail the measurements made, results obtained and how these data relate to the monitoring objectives. The frequency of reporting will depend upon the scale of disposal activity and the intensity of monitoring.

4. Part 4: References

Boyd, S.E. (compiler 2002). Guidelines for the conduct of benthic studies at aggregate extraction sites. London: Department for Transport, Local Government and the Regions.

CEDA & IADC (2008) Environmental Aspects of Dredging, Edited by R. N. Bray. Taylor and Francis.

Eleftheriou, A., & Holme, N.A. (2005). Macrofauna techniques. p. 140-216. In: Methods for the study of marine benthos Third edition (N.A. Holm and A.D. McIntyre, eds.). Blackwell Scientific Publications.

Fredette, T.J. (2006). Why confined aquatic disposal cells often make sense. Integrated Environmental Assessment and Monitoring, 2 (1) pp. 35-38.

Grasshoff, K., Kremling, K. & Ehthardt, M. (1999) Methods of Seawater Analysis. Wienhiem, Germany: Wiley -VCH.

IMO (2005). I537E Sampling and Analysis of Dredged Material at Sea, 2005 Edition. (Available at:
https://shop.imo.org/b2c_shop/app/displayApp/(cpgsize=25&layout=7.0-7_1_65_60_67_6_9_3&uiarea=3&carea=0000000062&cpgnum=1)/.do?rf=y)

Joyce, T. (1996). Inactivation of fecal bacteria in drinking water by solar heating. Applied and environmental microbiology , 62 (2), pp. 399-402.

Mudroch, A. and MacKnight, S.D. (1994) Handbook of Techniques for Aquatic Sediments Sampling, CRC Press, 256 pp.

Mudroch, A. and Azcue, J.M. (1995) Manual of Aquatic Sediment Sampling, CRC Press, 240 pp.

Myre, E. & Shaw, R (2006) The Turbidity Tube: Simple and accurate measurements of turbidity in the field. Department of Civil and Environmental Engineering, Master's Internal programme, Michigan Technological University, Technical brief.
ttp://www.cee.mtu.edu/sustainable_engineering/resources/technical/Turbidity-Myre_Shaw.pdf

Pequegnat, W.E. (1988) A technique for selecting an environmentally acceptable marine waste disposal site. Proceedings of an International Seminar on Environmental Impact Assessment of Port Development, Baltimore, Maryland, USA, 12-19 November 1988, 123-125.

PIANC EnviCom (2008) Dredged material as a resource. Report of Working Group 14 of the Environment Commission. International Navigation Association. Brussels, Belgium.

PIANC EnviCom (2006) Biological Assessment Guidance for Dredged Material. Report of Working Group 8 of the Environment Commission. International Navigation Association. Brussels, Belgium.

Pohle, G. WE., & and. Thomas, L.H.M (undated) Marine Biodiversity Monitoring Monitoring Protocol For Marine Benthos:Intertidal And Subtidal Macrofauna. A Report By The Marine Biodiversity Monitoring Committee (Atlantic Maritime Ecological Science Cooperative, Huntsman Marine Science Centre) To The Ecological Monitoring And Assessment Network OfEnvironment Canada.

Ohrel, R.L., & Register, K.M. (2006) Volunteer Estuary Monitoring A Methods Manual Second Edition. The Ocean Conservancy and EPA.

OSPAR (2009). OSPAR Guidelines for the management of dredged material. OSPAR 2009/4 (Available at http://www.dredging.org)

5. Part 5: Case Study

Case Study 1: Low tech approach to dredged material assessment for Karachi, Pakistan

Summary

Karachi Port Trust, conscious of the need to tackle the growing problem of environmental damage within the port area, commissioned an environmental study which included an assessment of the present impacts caused by dredging. As a signatory to the London Convention, Pakistan was required to assess the suitability of the material for dumping at sea.

The assessment, carried out in 1994/95, was based on the lines advocated by the London Convention (1972) and included sampling, analysis, assessment and classification of the material with regard to its suitability for marine dumping. It included an assessment of the dump-sites and consideration of possible beneficial uses of suitable material.

Short and long term strategies were recommended by the study team to implement changes to procedures and formation of an institutional framework for monitoring, assessing and controlling of the dredging operation

A follow up study carried out in 1997 showed the very real problems that developing countries have in complying with such international legislation as the London Convention. The key problems identified were public awareness, acceptance of responsibilities by appropriate bodies, availability of relevant scientific knowledge and the lack of financial resources to set up the control infrastructure and implement alternative dumping strategies. The ultimate, and probably the most crucial problem, was that the Port itself did not have the powers to control the discharges which were the main cause of the sediment contamination.

Site Description

Karachi Harbour (Figure 1) encloses an area of some 62 km^2 stretching from the sand spit in the west to China Creek in the East. The port itself occupies about 14 km^2, with 28 dry cargo berths and three oil berths.

It is a natural harbour which has been developed over more than a century by a process of reclamation and dredging. Although "rivers" drain into the harbour there is little rainfall and they carry mainly effluent. Pollution, and a substantial amount of the siltation in the inner harbour, is caused by the discharge of garbage, raw sewage and industrial effluents from the city. The main inputs are the Layari River and the Katchi Abadi sewage. Other sources of contamination are oil spills and organic waste from Karachi Fish Harbour. Identification and quantification of these sources would be crucial to the short term management of dredged material and the development of a long term strategy to control pollution at source.

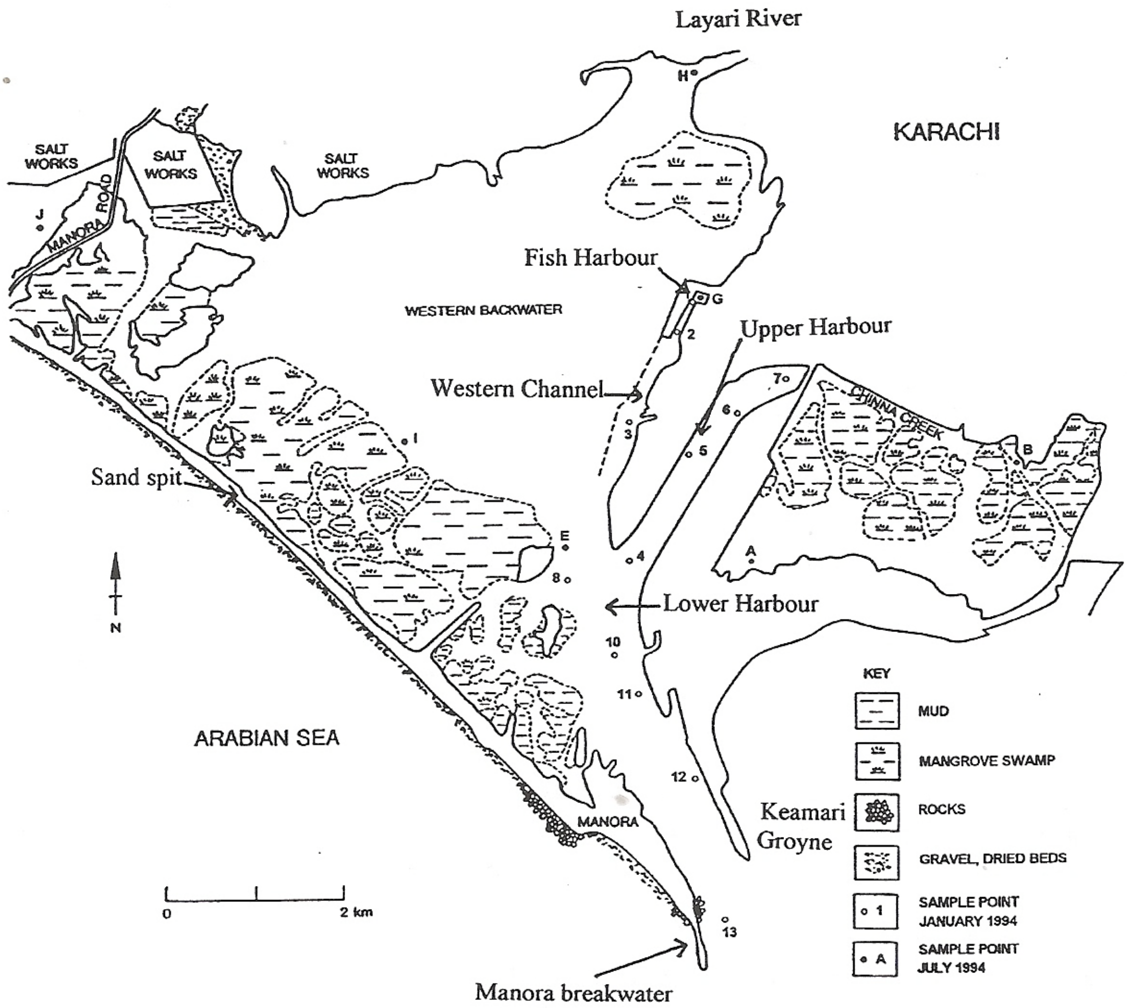


Figure 1: General location of Karachi Harbour

The population of Karachi grew rapidly following independence in 1947 and continues to increase rapidly, and so the problems can be expected to increase unless action is taken to control pollution. The present discharge of sewage and industrial effluents is estimated at a little under 200 mgd (million gallons per day). Although this is a high rate in terms of the amount of contamination it brings to the harbour, in terms of water discharge it represents less than 1% of the flow out of the harbour on spring ebb tides.

The hydrodynamic and sedimentation processes are dominated by the tides and the monsoon winds.

<u>Tides</u>
The maximum tidal range is 2.3 m. The whole tidal volume passes through the entrance between Manora and Keamari giving velocities in the entrance channel in excess of 1 m/s. Tidal currents also move along the coast.

<u>Monsoon winds</u>
The strong and persistent winds which occur during the monsoon season generate swell waves with a period of about 12 seconds in the Arabian Sea. They impinge on the Karachi coastline from a south westerly direction and are the prime movers of sediment in the area.

Sedimentation processes

The rate of siltation in the used part of the harbour, based on dredging statistics, is estimated to be about 1 million m^3/year. There are three sources:

60 - 65% generated by the monsoon
25 - 35% littoral drift from the sand spit
5 - 10% sewage

The coarse sandy material settles in and around the entrance and is easy material to dredge. The fine silty material penetrates to the harbour limits where tidal flushing is lowest or non-existent. It is harder to dredge efficiently because of its low density.

The heaviest siltation is experienced in the Entrance channel. Typically this may be 1 m loss of depth during the monsoon.

Material assessment

A small launch was used to collect samples, with a hand held 0.5 litre stainless steel grab, from different parts of the port area and from the existing dumping grounds. This technique was considered sufficient for the initial assessment as care was taken to prevent contamination of the samples by the grab itself. The sediment samples from the harbour were analysed to assess the material's suitability for dumping at sea.

Particle size

The samples were analysed using standard sieve techniques down to 0.063 mm diameter. The remainder was described as silt and was stated as a percentage of the total sample weight. The highest silt content (20 to 40%) was found in the samples in the Upper Harbour, Small Boat Harbour, Fish Harbour and West Channel. The lowest silt content (0 - 11%) was found in the Lower Harbour and the entrance channel bend. Knowledge of the percentage of silt is very helpful because contaminants generally tend to be associated with the finer particles, whereas sand containing little or no silt will usually be relatively free from contamination.

Outside the Harbour a clear trend exists. At the -20 m contour, the sediment is a very silty, fine sand (33% silt). The percentage of silt gradually reduces towards the shore, 28% at the -15 m contour, 21% at -10 m, 14% at -5 m and 2% at the -3 m contour. The beach material is a mica sand and contains no silt. This is consistent with the analysis of sediment mobility at the dump-sites discussed later. Also it demonstrates that there is an abundant supply of offshore silt that can be mobilised during the monsoon season and transported into the harbour by tidal action.

Trace Metals

Sub samples were sent to the UK for trace metal analysis. While this may be considered to be an advanced technique in some countries the costs incurred were acceptable within the resources of the project at the time. Many universities and commercial laboratories have such facilities worldwide.

The analysis showed that cadmium, mercury, cyanide and beryllium were close to or below the analytical limit of detection. The concentration of other metals varied considerably between sample sites, with values generally being highest around the upper harbour, and lowest in the Manora Channel and to the west of the Western Backwater. Two very high chromium (Cr) concentrations were measured in the harbour, one at the mouth of the Layari River, and one close to Baba Island. Cr has many industrial uses, for example chrome alloys, chrome plating, corrosion inhibitors, and in the textile, ceramic and glass industries, and is also present in sewage sludge. It is significant that leather processing is a major industry in the area. Levels in the outer harbour are considerably lower, consistent with the lower percentage of silt and that there are fewer inputs from port-related activities in that area.

Zinc concentrations were variable but generally around 200 ppm in the upper harbour, mouth of the Layari and part of the Eastern Backwater. It seems likely that the Lyari River is one major source.

The extremely high copper (Cu) content of the Eastern Backwater is surprising, as values were about 10 times greater than in the upper harbour area (Figure 2). Other metals measured did not display such elevated concentrations in this part of the harbour, which suggests a specific source of Cu in the Eastern Backwater. Levels around the main working areas of the port were variable, but an average concentration of 130 ppm is still high in comparison with other polluted ports.

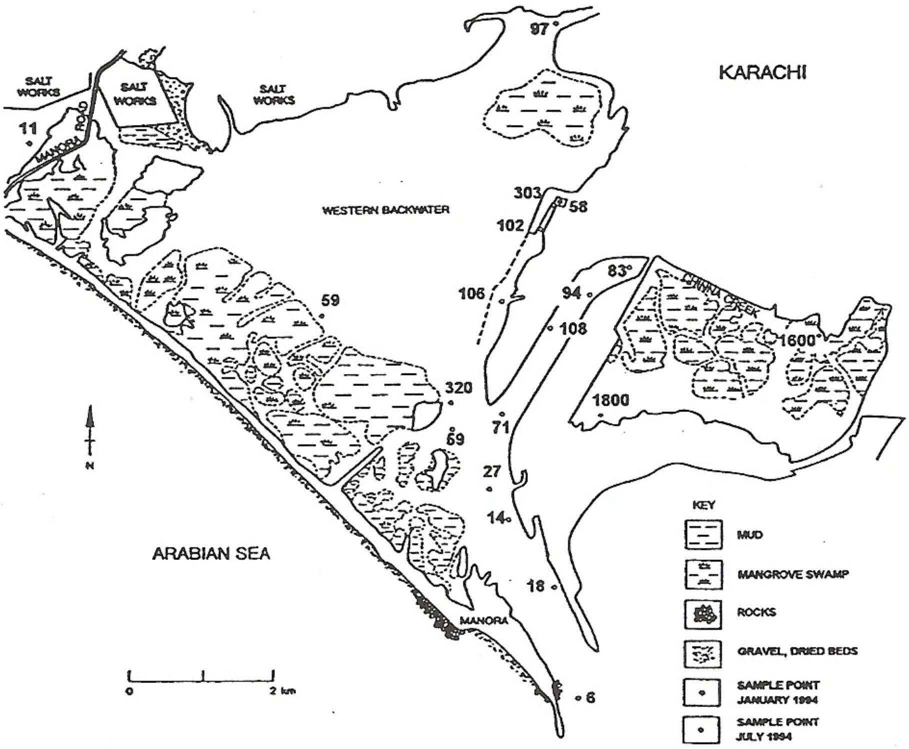


Figure 2; Distribution of copper in Karachi Harbour sediments

The distribution of Lead (Pb) concentrations in the Harbour are similar to those of Zinc. The high density of motor vehicles and the widespread use of leaded petrol in Karachi would be expected to result in high deposition rates of Pb from the atmosphere to the local marine environment. Pb can also reach the harbour waters from industries such as paint and battery manufacture.

Oil (Petroleum Hydrocarbons)

Among the main sources of oil pollution in the harbour are:

- The oil piers, mainly from leakages during transfer from ship to shore
- The tank farm area, Keamari
- Leakages from oil and chemical tankers
- Engine room bilges from general harbour vessels. Data on effluent from engine room bilges of harbour vessels are limited. However, information on the Pakistan Navy vessels indicates that engine oil and bilge water is pumped into the harbour once every 24 hours. The daily discharge is over 20 tons, and this increases when the ship is steaming.
- The Fish Harbour. Apart from oil spills from vessels in the Fish Harbour, the practice of dumping of fish waste into the confined waters of the fish harbour probably accounts for the very high levels of oil in the fish harbour sediments. This also contributes to the anoxic

conditions in the sediments and degradation rates are likely to be very slow.
- The cleaning of road transport vehicles in the port area, resulting in the discharge of oily effluent to the harbour.

Oil was detected at all sample sites, with some very high concentrations. For example, a concentration of over 30,000 ppm was measured in the Eastern Backwater.

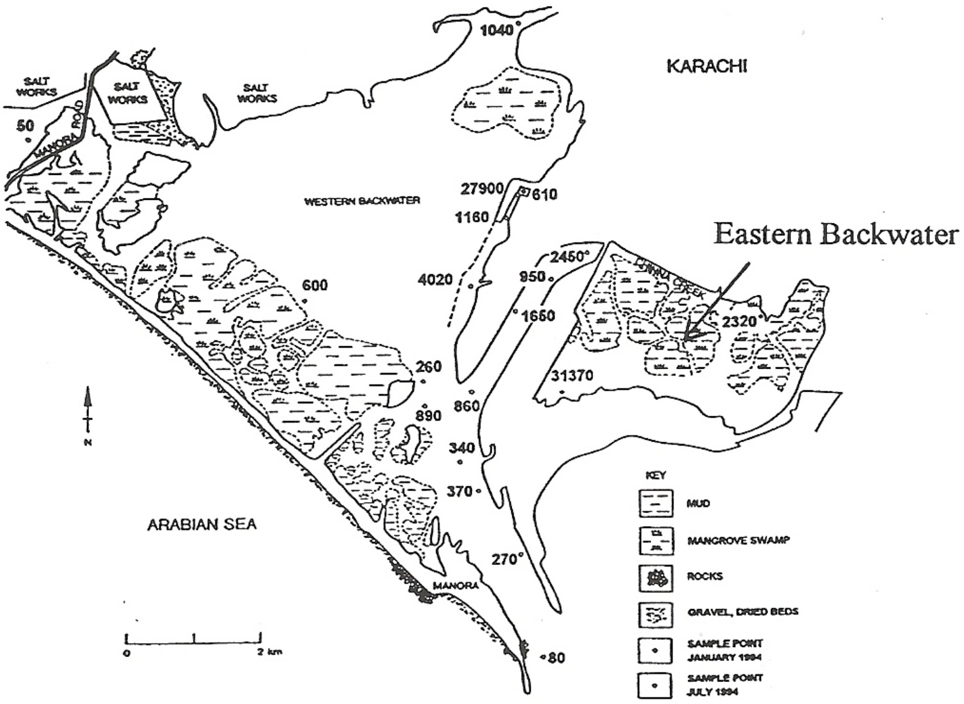


Figure 3: Distribution of oil

The presence of oil probably adds a further stress to the fragile ecosystems within the harbour area and could be particularly damaging to the mangroves ((Figure 3)

<u>Garbage</u>
There is a wide diversity of garbage including wood and plastic (with a particularly high proportion of plastic bags). This garbage probably originates in part from municipal waste and partly from Port activities. Water circulation patterns and wind-driven currents in the harbour area account for the accumulations in specific parts of the harbour.

Classification
The material to be dredged was classified using the Dredged Material Guidelines of the London Convention. The new protocol does not give specific guidance on standards but leaves each country to establish its own methods. The Annexes of the original version gave a useful starting point. Annex I substances (the black list) are prohibited for sea dumping. These are assessed below:

- Mercury and compounds were below the detection limit (2 ppm).
- Cadmium was below the detection limit (1 ppm) in all samples.
- Persistent plastics were found in samples from the Fish Harbour and in the Upper Harbour. Although not found in other samples there is a visible presence of plastic bags all over the harbour.
- Oil and oil products were found in all samples from the harbour and were especially high in the Eastern Backwater and in the Fish Harbour (around 30000 ppm).

- Radioactive substances were not fully tested on the grounds of very high cost. A simple Geiger Counter test on the samples showed no levels higher than background.

The presence of persistent plastics and chronic oil pollution required further consideration. Exemption can be given if it can be demonstrated that the items are rapidly rendered harmless or are only present in trace quantities.

Whilst there was no absolute standard, it was determined within the project that concentrations above 1000 ppm would be regarded as too high for marine dumping. The evidence for the oil is that whilst it may be rendered harmless it is probably not a rapid process. Persistent plastics were found in the Upper Harbour and in the Fish Harbour and not in the Lower Harbour. Overall the material from the Lower Harbour is therefore considered acceptable for marine dumping based on the assessment of the oil and plastic levels.

It is also necessary to consider the Annex II substances which should not be present in "significant" amounts. Significant was determined in this project to mean not more than 0.1% (i.e. 1000 ppm) for substances except lead for which it means 0.05% (500 ppm).

1. Arsenic not significant
2. Lead not significant
3. Copper not significant
4. Zinc not significant
5. Cyanide not significant

Other items in the list require more complex and expensive analysis.

Thus under the London Convention there are no tested Annex II substances present in sufficient quantities to warrant special control measures.

Attempts have been made by some countries to establish absolute standards and this is a continuing process. For example Hong Kong at the time of the study had adopted a classification system based on heavy metal concentrations in Table 1:

Table 1; Classification by Hong Kong Standards

Class	**Cu**	**Cd**	**Cr**	**Pb**	**Ni**	**Zn**	**Hg**
A	28	0.40	25	35	25	75	0.2
B	55	1.00	50	65	35	150	0.8
C	65	1.50	80	75	40	200	1.0

Class A: General background levels. Sediment with concentrations below the threshold for Class B are regarded as uncontaminated.

Class B: Sediment with concentrations above the stated levels is regarded as mildly contaminated.

Class C: Sediment with concentrations above the stated values are regarded as highly contaminated.

For the purposes of the Karachi assessment another class was introduced,

Class C+: very highly contaminated, having concentrations more than 4 times the Class C limit.

Under this classification only Class A can be disposed of in the normal way. Class B requires special care and Class C has to be totally isolated from marine organisms and human life (including during handling).

The average metal concentrations for samples for each area have been assessed on the Hong Kong scale in Table 2. Note that the detection level of Mercury (Hg) was set too high (2 ppm) for these standards

Table 2: Classification by Hong Kong standards

Location	Cu	Cd	Cr	Pb	Ni	Zn
Fish Harbour	C+	A	C+	C	C	C
West Channel	C	A	C	A	C	C
Upper Harbour	C+	A	C	A	C	B
Lower Harbour	A	A	A	A	A	A
Outer Channel	A	A	A	A	A	A

In mitigation of these standards the receiving waters in Karachi have a greater assimilative capacity and the quantity of material to be disposed of is much less than in Hong Kong waters. Nevertheless, the concentrations of Cu, Cr and Zn give rise to real concern about the suitability of some of the material for dumping.

Classification zones

Having established the degree of contamination the next step is to classify the material for dumping, attempting to minimise the quantity that will require special handling.

Class A: Mainly Uncontaminated

Uncontaminated or mildly contaminated material for which no special dredging, transport or dumping methods are required. This will be mainly sandy material (generally less than 10% silt), meeting the criteria of the London Convention and comparing favourably with the Hong Kong standards for heavy metals. The material deriving from the Lower Harbour (with some reservation regarding the oil content), Entrance Channel bend and Outer Channel would all be expected to fall in this class, with regard to both maintenance dredging and capital dredging. The material is regarded as suitable for marine dumping at an approved site or sites and may be suitable for certain beneficial uses.

Class B: Moderately contaminated

Moderately contaminated sediment which requires special care during dredging and transport and which must be disposed of in a manner which ensures effective isolation and minimum loss of pollutants either into solution or by resuspension.

At the present time there is not a significant quantity of material which could be classified as moderately contaminated. However, with remedial action regarding the plastics and oil most of the future siltation material would soon become Class B.

Class C: Highly contaminated material

Highly contaminated material which must be dredged and transported with great care and must be permanently isolated from the environment. It should not be placed in marine dumping grounds.

All of the material in the Upper Harbour, Western (PIDC) Channel, Fish Harbour and the Small Boat Harbour should be regarded as Class C

Beneficial use of Class A material

The London Convention's Dredged Material Assessment Framework (DMAF) requires that consideration is given to possible beneficial uses of the material before a permit for dumping can be granted.

Class A sediments collected from the frequent dredging of the Karachi Harbour could in the future be deposited on land around the Port. The Port Authorities are considering expanding areas of the Port by reclaiming land and using the dredged sediments for infilling. The low levels of silt would be acceptable for this purpose.

Another beneficial use for Class A material would be as a capping material for the contaminated sediment (see Other Options below).

Class C material is not considered suitable for beneficial use without treatment (see above).

Handling of Class C material

The World Bank Guidelines recommends consideration of the type of dredging equipment to be employed for each zone. At the time of the study the lack of marine life in the Class C areas meant that little damage would result from disturbance of the polluted sediment. If the clean up of the water quality precedes the removal of the contaminated sediment then special care will be necessary in the dredging operation to avoid high turbidity levels. In the meantime any of the available dredging plant was acceptable from the point of view of the marine environment.

From a health and safety point of view the dredge operators should be advised that they are handling contaminated material with possible harmful effects. Those coming into direct contact with the material should wear protective clothing to avoid undue skin contact. Precautions such as washing before handling food are important.

Dumping options

Open water dumping

Having classified the material regarding its suitability for sea dumping it is now necessary to consider the potential impacts at the dump-site(s). The location of the existing sites is shown in (Figure 4).

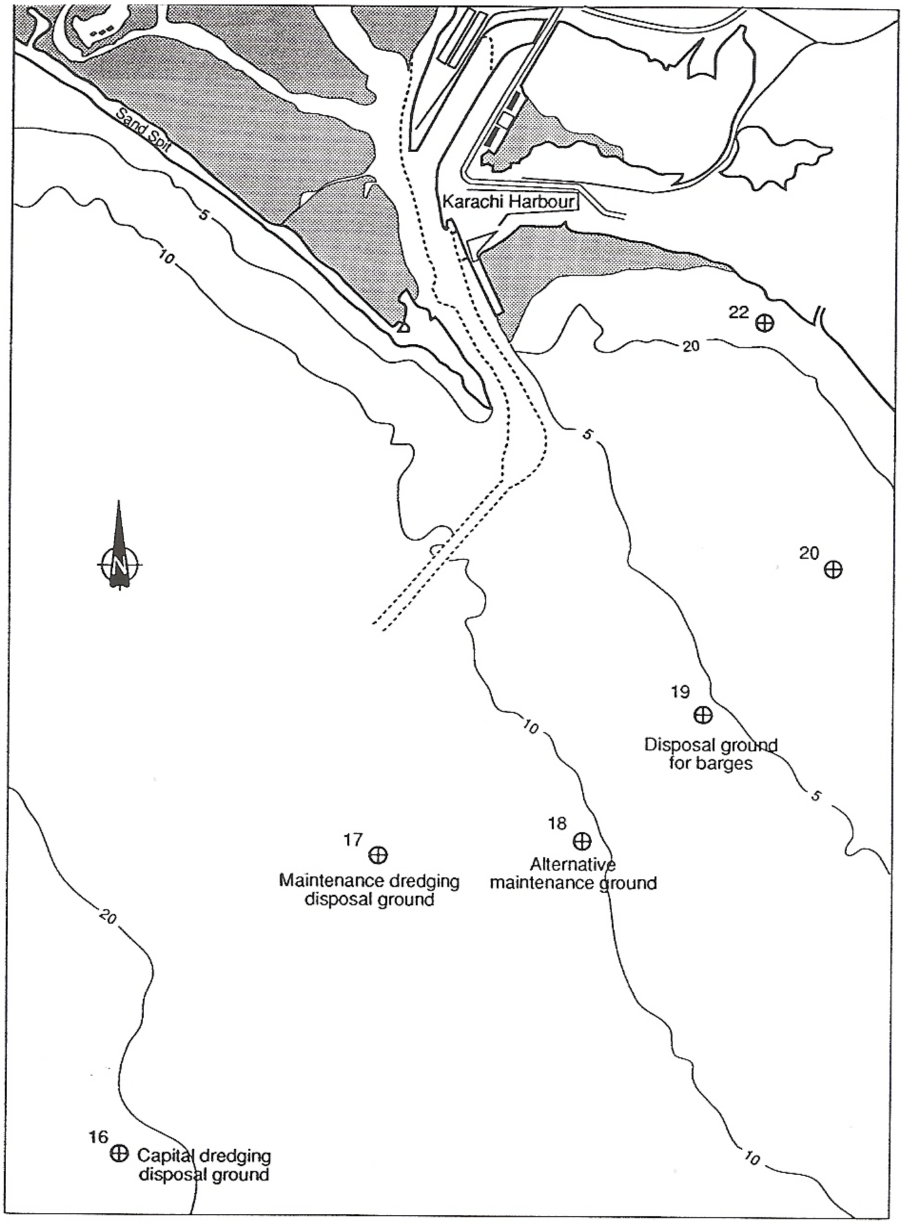


Figure 4: Existing open water dump-sites

A useful guide to its dispersion or stability can be obtained by further examining the existing sediment transport regime. Water depths, tidal variations and tidal current information are usually available from published charts and tables. Currents and wave action are important factors in mobilising and transporting material over the seabed off Karachi, and these are now considered in turn.

Tidal effects

Since any dredged material will probably be placed in relatively deep water, it is sufficiently accurate to assume that Mean Sea Level (MSL) is 1.6 m above CD, and that around this level the larger tide varies by plus or minus 1.2 m, and the smaller tide by plus or minus 0.6 m, over about a 12-13 hour period.

Peak tidal currents away from the harbour entrance are generally about 0.2 - 0.4 m/s depending on tidal range. Table 3 has been prepared to show the percentage of time that various current speeds are exceeded at 8 m depth.

Table 3: Tidal current speeds and time exceeded at 8m depth

Current speed m/s	0.05	0.10	0.15	0.20	0.25	0.3	0.35	0.4
Time exceeded %	99	92	61	36	15	8	5	0

These figures were used to calculate the grain sizes of sands which might be mobilised at 8 m depth by the tidal currents alone using published formula. The conclusion was that in depths greater than 8 m, the tidal currents will not mobilise and transport sand on their own. It is likely that dispersion of dredged material by tidal currents alone will only occur if it is placed in water shallower than 5 m.

This ignores the effects of waves; even in the non-monsoon months there is often low swell wave activity, typically up to 15 cm in height and of 12-15 seconds period (Figure 5). Although they are hardly noticeable on the water surface, they have a significant effect at the seabed, helping to mobilise the sediment particles. In the monsoon season, sediment mobility will be dominated by the persistent large waves. Data was already available for neighbouring Port Qasim.

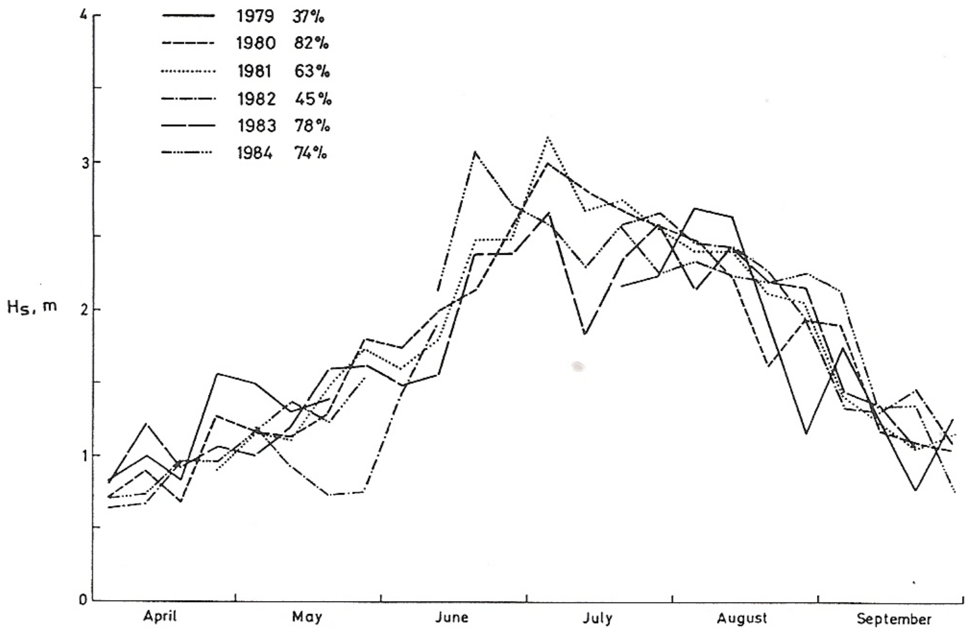


Figure 5: Wave climate at port Qasim

Knowing the grain size of the material, the wave climate and the tidal currents it was possible to calculate the sediment mobility at various depths offshore, corresponding to existing dump-sites. The conclusions were that:

1. Tidal currents alone are unlikely to mobilise or disperse sediment on the seabed at depths less than about 5 m CD.

2. In contrast, at the height of the South-West monsoon season, i.e. in July, the persistent large waves are likely to mobilise medium-sized sand in depths of 20 m.

3. Both the tidal flows and wave-induced currents in the surf-zone are likely to result in a net south-eastward transport of seabed sediment, i.e. from Karachi toward Korangi Creek.

4. The existing dump-sites for maintenance dredgings are both suitable. Both of these sites are dispersive but dispersion takes place during the monsoon season and excessive loading of one area in the non-monsoon period could result in the creation of a navigation hazard both for the dredger and for other vessels approaching Karachi from the south.

5. The existing dump-site for capital dredgings, beyond the -20 m contour, is also satisfactory. Again care should be taken to avoid too great a build up of bed levels during the non-monsoon period.

6. The dumping ground used by the barges near the -5 m contour has become contaminated with oil. The site remains satisfactory for Class A material. The dumping of contaminated material from the Upper Harbour etc at this site should be phased out. This should result in a gradual improvement in sediment quality at this site. There is no merit in allocating another site in a similar environment close by because this would simply spread any problems over a wider area.

It could be argued that because there is little sign of contamination at the dump-sites, because of the dispersion and dilution with clean sediment, there is no need to restrict future dumping of contaminated sediments at these sites. It is emphasised that this is not considered a valid argument by the Conventions because it means that the contaminants are being released into the marine environment and the consequences of that are not fully known. The precautionary principle therefore applies and containment and isolation are generally the preferred options.

Other options must therefore be considered for the Class C material.

Conclusion

The case of Karachi demonstrates that it is possible to carry out an assessment of the dumping of dredged material without having a major investigation comprising sophisticated sampling and extensive contaminant analysis, computer modelling etc. In this case:

- Potential sources of contaminants were investigated by consultation with various government and private organizations, including local environmental groups.

- Sampling was done using a small hand-held grab from a survey launch;

- The percentage of silt was determined by simple sieve analysis;

- Heavy metals were determined by a lab outside of the country;

- While some contaminants listed in Annex II were not analysed it was thought unlikely that the overall classification would change even if they were found to be present in significant quantities. In other words the sediments where they might be found were already classified as contaminated.

- The quantities to be dredged were determined by the port authority as part of the their normal port maintenance operation;

- A classification system was developed based on the Convention's Dredged Material Assessment Framework and standards for heavy metal concentrations adopted by Hong Kong.

- The classification of the sediments was then used along with knowledge of sources of contamination to classify areas within the harbour by degree of contamination, thus avoiding the need to treat all of the sediment in the same way. This meant that Class A material could potentially be used beneficially or disposed of at minimal cost. It further meant that there was no need for continuous assessment of the quality of the sediment. When dredging in a particular area was required, the Port already knew how the material should be handled. Of course the condition of the sediments should be reviewed from time to time as measures to control sources of contamination gradually take effect.

- Existing dump-sites were reviewed on the basis of existing knowledge concerning the sediment type, waves and currents. Tidal velocity data is often available from Admiralty Charts. Wave data is available from published recorded ship observations. While some expert knowledge was required to assess the mobility of sediments under various conditions the basic conclusion that the main site was a dispersive site was obvious from the fact that bed levels had not changed despite regular placement of dredged material for many years.

Consideration of what to do with contaminated material not suitable for sea dumping is outside of the scope of the convention but there is "grey literature" that can be helpful such as that published by CEDA and PIANC. Recommendations were given to Karachi Port Trust but do not form part of this case study.

Implementation
A follow up study carried out in 1997 showed the very real problems that developing countries have in complying with such international legislation as the London Convention and Protocol. The key problems identified are:

<u>Public awareness:</u> People generally were not aware of the damaging effects that their actions (or lack of them) have on the marine environment. Simple measures such as not throwing plastic bags into the street could reduce the amount of dredged material classified as contaminated.

<u>Acceptance of responsibilities by appropriate bodies:</u> There was no clear institutional link between Government policy and implementation. Pakistan had signed the London Convention but at the time of the review did not have a body appointed to issue permits.

<u>Availability of relevant scientific knowledge:</u> At the time of the investigation there was not a sufficient level of specialist knowledge available in the country to carry out sophisticated procedures such as bio-assays and the interpretation of their results.

<u>Lack of financial resources:</u> to set up the control infrastructure and implement alternative dumping strategies. The cost even of setting up a laboratory capable of analysing sediments for, e.g. organohalogens is considerable.

<u>Source control:</u> The ultimate solution, and probably the most crucial problem, is to control the discharges that are the main cause of the sediment contamination. The Port itself did not have the necessary powers.

Appendix 1

Turbidity tube: How to construct and use a turbidity tube (Adapted from Myer and Shaw (2006))

A turbidity tube can be purchased commercially, or can be constructed at an extremely low cost using a wide range of locally available materials. It is particularly well-suited to situations when decisions can be made based on approximate turbidity (rounded to the nearest 5 NTU).

The turbidity tube uses the correlation between visibility and turbidity to approximate a turbidity level. A marker is placed at the bottom of the turbidity tube until it can no longer be seen from above due to the “cloudiness” of the water. This height from which the marker can no longer be seen correlates to a known turbidity value. Although this correlation is less accurate than what would be obtained from other methods, it is almost certainly accurate enough in a low technology environment. Generally, the cost savings of using a turbidity tube outweigh this loss of accuracy.

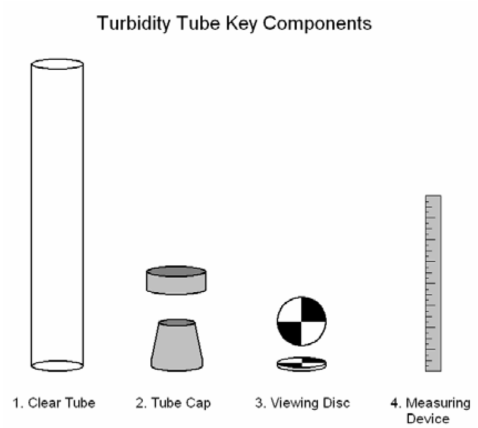


Figure 1: Turbidity Tube Key Components

Key Components

A turbidity tube is made up of four key components (see Figure 1):

1. A Clear Tube
2. A Tube Cap
3. A Viewing Disc
4. A Measuring Device

(1) **Clear Tube**: The clear tube will hold the water sample being tested. The tube must be clear to allow for maximum light reflectance off of the marker being viewed. Even a light coloured or white plastic tube will not let in enough light for the tube to work properly. A clear plastic tube will provide the most durability and reduce the chances of damage during transport, but a glass tube can be used if handled with caution. Possible Clear Tube Materials: Fluorescent light sleeve, graduated cylinder, etc.

(2) **Tube Cap**: The tube cap prevents the water sample from leaving the clear tube. A seal to the end of the tube can be used, but a removable tube cap is preferred for cleaning of the tube and view disk. Make sure that whatever cap is used it prevents leakage (a good seal is more important than removability). The size of your cap will depend on the size of your tube. Possible Tube Caps: Rubber stopper, PVC pipe cap, Gatorade lid with rubber washer, chair leg end cap, etc.

(3) **Viewing Disc**: The viewing disk will be submerged in the water sample. A clear pattern must be visible on the disk as well. Generally, it is best to use a white background that is coloured with a black checker pattern (this is the pattern typically found on a Secchi disk as well). The contrast makes the viewing disk very clear, which improves the accuracy of the reading. A white plastic disk patterned with black permanent marker works extremely well. The disk should be sized to fit inside the plastic tube. If necessary, the disk can be made of a porous material such as wood or cardboard, but it must be sealed by lamination or with varnish. Possible Viewing Discs: Yogurt container lid cut into a circle, white poker chip, etc. Possible Marking Device: Black permanent marker, black paint, etc.

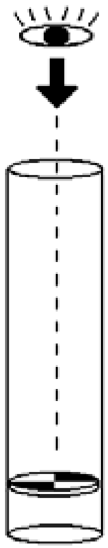
(4) Measuring Device: The level of the water at the point of non-visibility needs to be measured. This can be done in two ways. The water level can be directly measured from the viewing disc to the top of the water, and a chart can be used to find the turbidity level that corresponds to the measurement. A better way is to mark the turbidity tube with the corresponding turbidity levels before testing begins so that no conversion is necessary. Your choice will depend on the availability of materials and the construction of your tube (for example, if the removal and reinsertion of your tube cap changes the height of your viewing disk, the marking will no longer be correct). Possible Measuring Device: Ruler, tape measure, etc.

General Construction

As stated earlier, these instructions are very broad to encourage adaptations in the design. After obtaining the materials discussed above, do the following:

Step 1: Plan the Placement of Viewing Disk

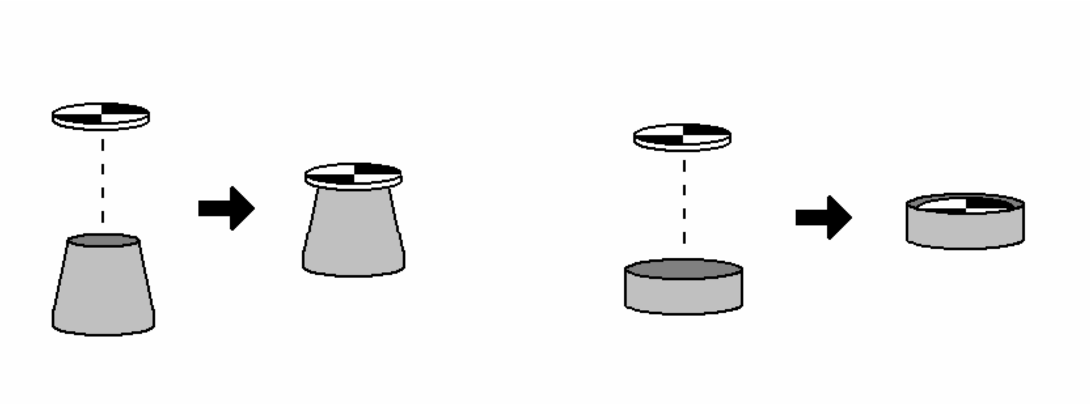
You will need to be able to see the viewing disk from the top of your clear tube. The placement of the disk will depend on your tube cap. The disk can be dropped to the bottom of your tube if it is not made of a floating material. A dropped disk will need to be marked on both sides. You can also attach the disk to your tube cap with adhesive so that it will be visible when the cap is inserted. Another possibility is to mark the tube cap with a chequered pattern so that it can be treated as a viewing disk.



Step 1: Viewing Disk Placement

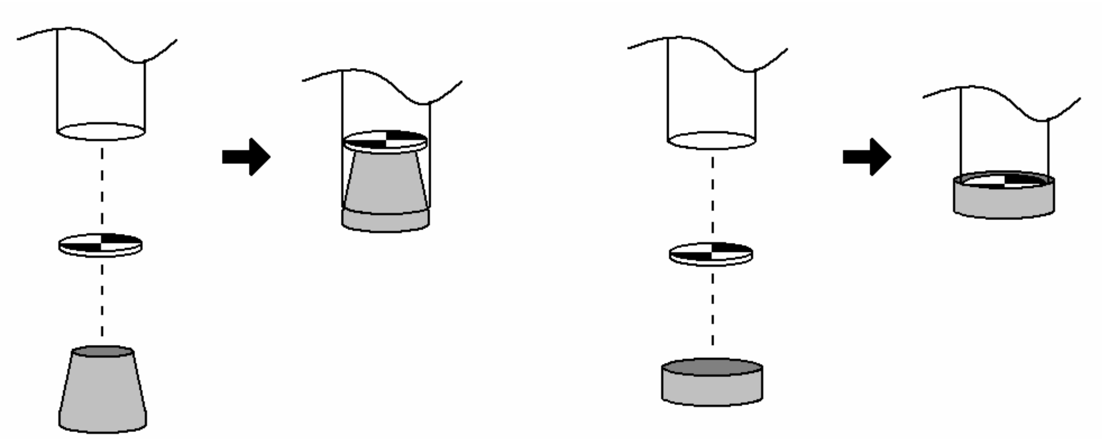
Step 2: Combine Tube Cap and Viewing Disk

Here, you can use adhesive or sealant to bind the viewing disk to the tube cap. Make sure the disk will fit properly when the tube cap is inserted into the tube (i.e. try it before you glue it). Again, you can also mark the chequered pattern directly on your tube cap, or a nonfloating disk can be dropped from above (just make sure it is small enough as to not get stuck in the tube or the bottom).



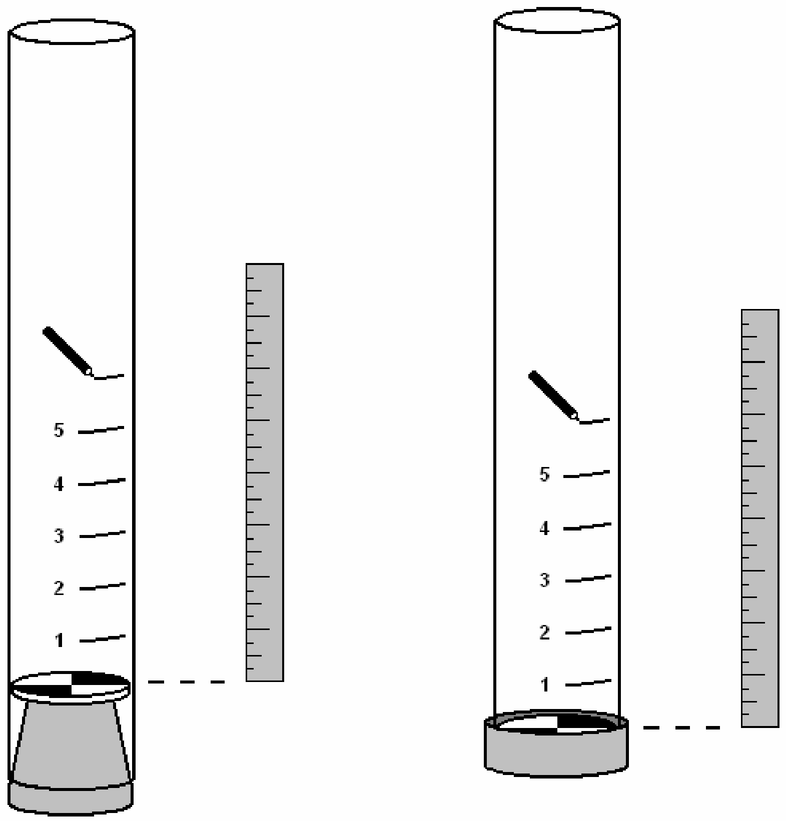
Step 2: Combining the Tube Cape and Viewing Disk

Step 3: Affix Tube Cap to Bottom of Tube
Ideally, the tube cap will be removable for cleaning, but the primary concern is that water does not escape the tube during testing. Some sort of sealant or putty can be used to seal the cap well. Make sure the disc is still clearly visible from the top of the tube.



Step 3: Affixing the Tube Cap to the Tube Base

Step 4: Mark Tube with Measurement Increments
Ideally, the turbidity level will be marked directly onto the tube. Place the zero mark of a measuring tape or ruler *level with the viewing disk* and measure up the tube, marking the proper intervals found in Table 1. Two rubber bands on each end of the tape will hold it in place well while you mark levels. If the tube is not easily marked, measurements in centimetres can also be taken and then used to find the corresponding turbidity in Table 1.



Step 4: Marking Measurements on the Tube

The tube should now be complete. After all components have dried, test the tube for leakage and make adjustments accordingly. If you are not able to mark the tube directly and will be measuring the depth of the disk below the surface for each reading, try to attach the measuring device to the side of the tube (again, rubber bands work well).

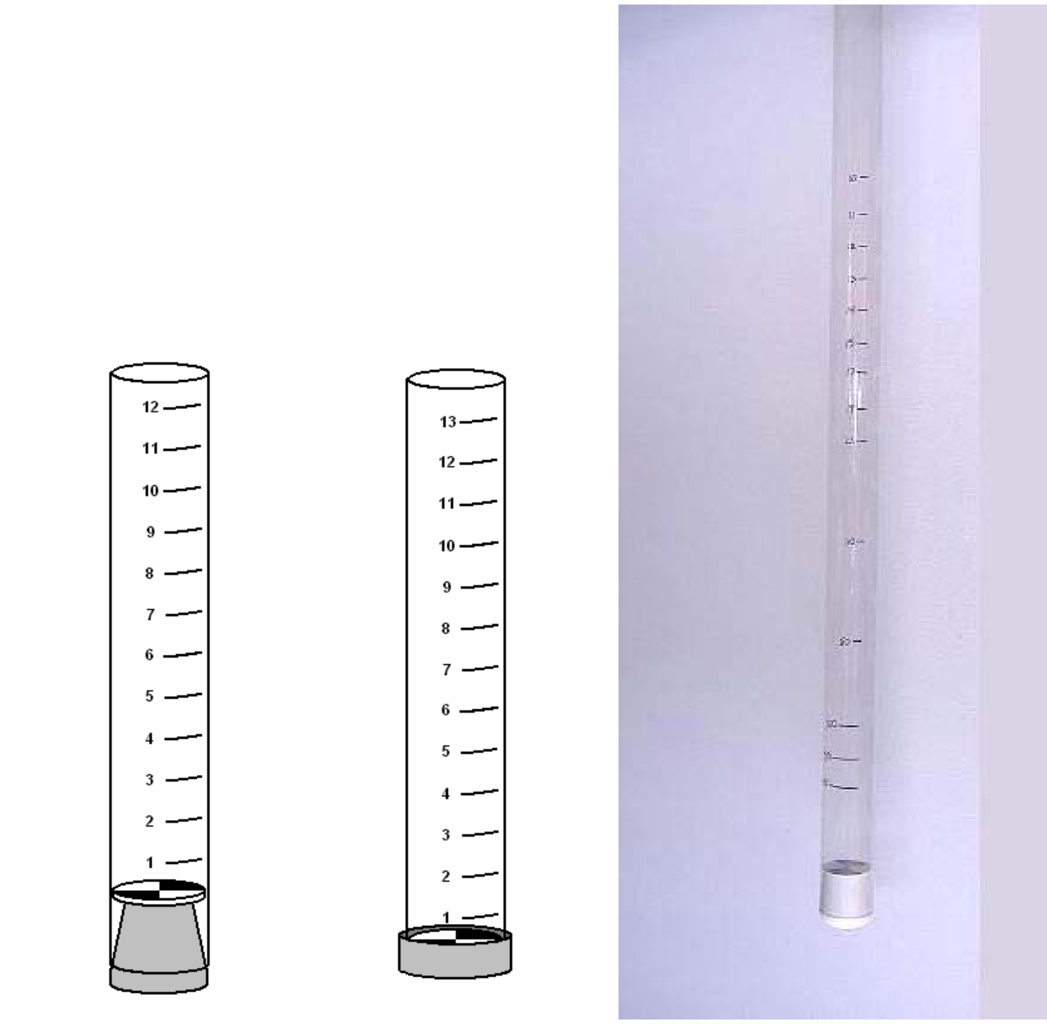


Figure 2: Completed Turbidity Tubes

Of the available approaches to turbidity testing, a turbidity tube is the most appropriate method to test water when funds are limited. The turbidity tube is inexpensive, easy to use, and does not need to be restocked with batteries or testing supplies. A turbidity tube can be understood intuitively, even by non-engineers. Moreover, the use of a turbidity tube conveys more information about what is being measured than looking at a read-out on a digital screen does. This provides an opportunity to educate community members about many water quality issues, including source protection and treatment options. Turbidity tubes are also very portable and are designed for use in the field. This is an added benefit; turbidity is more accurately measured on-site as it can change rapidly during transport or storage (WHO, 2004).

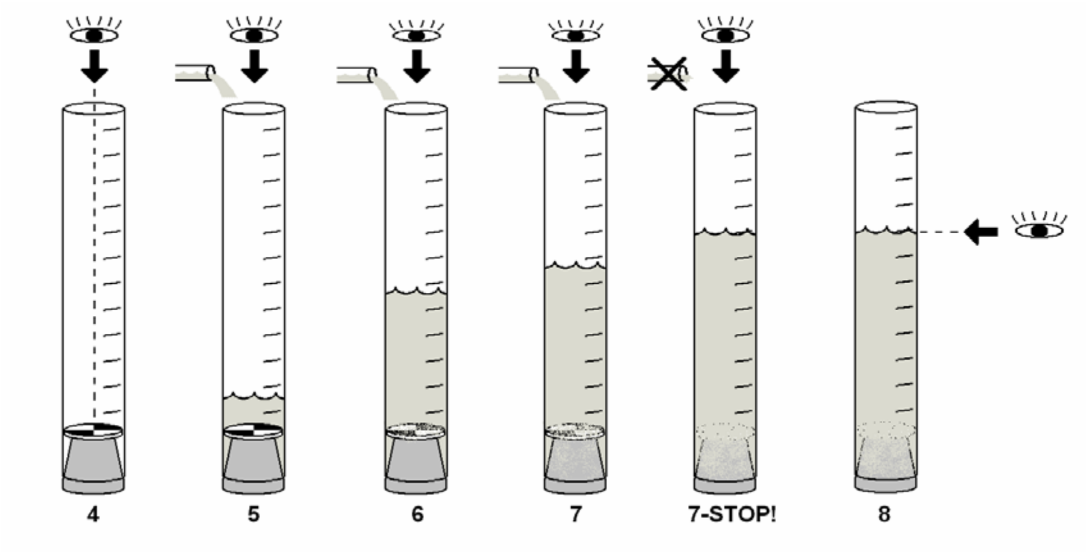


Table 1. Centimetre – NTU conversion table

Depth in Centimetres = 244.13 *(Turbidity in NTU)-0.662

Centimetres	NTU
6.7	240
7.3	200
8.9	150
11.5	100
17.9	50
20.4	40
25.5	30
33.1	21
35.6	19
38.2	17
40.7	15
43.3	14
45.8	13
48.3	12
50.9	11
53.4	10
85.4	5