SECTION 3 BENEFICIAL USES OF DREDGED MATERIAL

3.1 Beneficial Uses of Dredged Material

3.1.1 Beneficial Use Options

Responsible dredged material disposal provides opportunities for a number of environmental, economic and aesthetic beneficial uses. Innovative beneficial uses appear to be extensive and over 1,300 cases of beneficial uses of disposal sites have been documented in North America alone (USACE, 1985). Parallel experience in the U.K. is, however, severely limited. Table 3.1.1 shows a variety of beneficial use applications of dredged material in North America.

Ten broad categories of beneficial uses can be identified based on the functional use of dredged material at disposal sites. They are:

i) Habitat development (wetland, upland, island, aquatic, including migratory and nesting use by waterbirds, shorebirds, waterfowl and other groups).
ii) Beach nourishment.
iii) Aquaculture.
iv) Parks and recreation (commercial and non-commercial).
v) Agriculture, forestry, and horticulture.
vi) Open cast mine reclamation and solid waste management.
vii) Shoreline stabilisation and erosion control.
viii) Construction and industrial use (including port development, airports, urban and residential).
ix) Material transfer (fill, levees, parking areas, roads).
x) Multiple purpose.

As land use has intensified and areas available for dredged material disposal have become scarce, the concept of beneficial use of dredged material for initiatives such as habitat creation have become more attractive economically. This report concentrates on the beneficial uses of dredged material for nature conservation directly (e.g. habitat creation) and also reviews indirect benefits (e.g. beach nourishment). Section 3 of the report concentrates on the beneficial uses of clean dredged material. Section 4 deals with contaminated dredged material.

3.2 Legislative, Environmental and Economic Considerations

3.2.1 Restrictions on Dumping Material in the Subtidal Environment

Dumping of dredged material at sea, or under the seabed, in the U.K. is controlled under the Food and Environment Protection Act 1985 (as amended by the Environment Protection Act 1990). This Act requires that a licence is obtained for the deposit of substances or articles either in the sea or under the seabed, within United Kingdom territorial waters (from low water out to 12 miles offshore). It also outlines considerations which are followed in determining whether or not to issue a licence. The administration of the licensing system is carried out in England and Wales by the Ministry of Agriculture, Fisheries and Food.

Table 3.1.1 **Beneficial Use Applications of Dredged Material ***

State	Wetlands	Waterbird Nesting	Other Habitat Develop.	Recreation (all types)	Agriculture Forestry	Beach Nourishment	Commercial + Residential	Industrial Institutional	Stabilization (bank/shore)	Flood Control Hurricane Prot.	Sanitary Landfill	Total
Alabama	5	16	2	4		1		13		1		42
Arkansas				2								2
California	9	23		17	2	3	9	15		1		79
Connecticut	7	7	1									15
Delaware	2	6		2				1				11
Florida	14	39	2	6	1	26	3+	11	1	2	1	106
Georgia	5	15	2	1		1		4	1	1		30
Illinois		2	2	4				2				10
Indiana				1								1
Iowa				5								5
Kentucky	1		1									2
Louisiana	5	31	3	8	1	1	6+	5+		3+		61
Maine	1	4										5
Maryland	19	8	2	5		3	2	5+				44
Massachusetts	2	11										13
Michigan	2	29	6	16				2+		2		57
Minnesota	3	2	2	4			1	4				18
Mississippi	8	23	3	2		2	3	2	2	1		46
Missouri	1			5			1	1				8
New Jersey	2	49			1	1		3+				56
New York	11	29	3	4		4	1	6+			1	59

State	Wetlands	Waterbird Nesting	Other Habitat Develop.	Recreation (all types)	Agriculture Forestry	Beach Nourishment	Commercial + Residential	Industrial Institutional	Stabilization (bank/shore)	Flood Control Hurricane Prot.	Sanitary Landfill	Total
North Carolina	10	81	1	2		4	2	2		4		106
Ohio		2	5	7				5+				19
Oklahoma					1							1
Oregon	5	18	8	3	2	1	3	8+	3	1	1	53
Pennsylvania		1	1					1+				3
Rhode Island		5										5
South Carolina	1	11	3	2	2	1	2	3				25
South Dakota				1						1		2
Tennessee				2		1	1					4
Texas	9	242	1	5	3	1	1+	13+	1	1		277
Virginia	17	22		1		1		3	1			45
Washington		7	13	21	1		3	23+			1	69
Washington, DC				1			2					3
West Virginia				1								1
Wisconsin	2	2	2	4			1	4	1			16
Canada		28	1			1	3+					33
Total	139	713	65	136	14	52	44+	137+	11	17+	4	1,332

Source: U.S. Army Corps of Engineers (Date unknown).

* Wetlands and other habitats built as mitigation, but that were not built on dredged material, are not included in this listing. Several hundred such beneficial use projects have already been built or are in planning.

\+ Some sites in these states were so numerous, especially in highly urban areas where dredged material has been used for many years for residential, commercial, and industrial fill, and for levee construction, that they were impossible to count.

Under the terms of the Food and Environment Protection Act, any dumping to be carried out in the sea:-

a) shall have regard to the need:

i) to protect the marine environment, the living resources which it supports and human health; and

ii) to prevent interference with legitimate users of the sea;

and

b) may have regard to such other matters as the authority considers relevant.

The Ministry of Agriculture, Fisheries and Food (MAFF) currently issues licences for the deposit in the sea of solid and liquid industrial wastes, sewage sludges and dredged material. Before a licence is granted MAFF carry out chemical analysis on the sediment to be dumped to determine the pollutant load of the material. This analysis in turn determines the required dumping procedures.

The disposal of dredged material in controlled waters is covered by the Water Resources Act 1991. Under this Act it is an offence to cause or knowingly permit without consent any poisonous, noxious or polluting matter or any solid waste matter to enter any stream or controlled water.

3.2.2 Restrictions on Dumping Material in the Intertidal Environment

The legislation relating to the dumping of material in the intertidal environment is the same as that required for dumping material in the terrestrial environment as the relevant Acts are applicable down to low water mark. These Acts are outlined in Section 3.2.3 below.

3.2.3 Restrictions on Dumping Material in the Terrestrial Environment

The Town and Country Planning Act 1990, Part III, states that when the deposit of refuse or waste materials requires a material change in land use, planning permission will be required. This applies to the dumping of material down to low water mark.

Under the Environment Protection Act 1990, Part II, it is the duty of any person who imports, produces, carries or disposes of controlled waste to take all measures applicable to him as are reasonable in the circumstances, inter alia, to prevent harmful deposition and to prevent the escape of the waste from his control. This may have implications for the dumping of dredged material, depending on the characteristics of the material.

Under the Town and Country Planning Act (Assessment of Environmental Effects) Regulations 1988, it is not mandatory to carry out an Environmental Assessment when dumping material in the sea or on land. The government, however, has given guidance on cases which may need discretionary Environmental Assessment: the general test is whether the project will have 'significant' environmental effects, and it must be either a major development of more than local importance or occasionally a small-scale project in a sensitive or vulnerable location. The latter might be particularly relevant to the disposal of dredged materials in the intertidal area.

3.2.4 Guidelines for the Disposal of Maintenance Dredged Material

To date, there are no U.K. guidelines for terrestrial or intertidal disposal of dredged material. With regard to subtidal disposal, MAFF follow their own internal guidelines, although in general each case is considered on its own merits. Guidance on terrestrial, subtidal and intertidal disposal guidelines in the U.K. and other industrially developed countries is discussed in more detail in Sections 4.2.3 and 4.3.3.

3.2.5 Environmental Accountability

The identification of potential sites for habitat creation schemes should consider not only technical and economic criteria, but also the existing and potential nature conservation, landscape and recreational value of the site. Potential sites for dredged material use should ideally have little or no existing conservation interest. The current interest of the site can be ascertained through consultation with:

- nature conservation organisations (e.g. English Nature, Royal Society for the Protection of Birds, County Trusts, and others).
- recreation and landscape organisations (e.g. Countryside Commission, local authorities and others).

Any designations which the site already has must be defined and their requirements taken into consideration during the site selection procedure. This may include statutory designations, e.g. Sites of Special Scientific Interest, Marine Nature Reserves or non-statutory designations, e.g. Voluntary Marine Conservation areas. Sites which may be affected in the adjacent areas or near vicinity should also be considered in terms of indirect effects.

The sites which are to be created or restored may have significant potential as sites which can be developed as nature reserves, recreational, amenity and landscape areas. It is important, therefore, during the planning stage to define the habitat goals and to assess landscape, recreation and nature conservation as a whole and not in isolation (see Appendix C).

3.2.6 Economic Criteria

- Disposal Costs

The costs of disposal of maintenance dredged material at a licenced disposal area varies considerably depending on the distance the dredger must travel from the dredge site to the disposal site and on the type of material which is to be dredged and disposed of. Costs are estimated at between £2 to £15 per m^3, for dredging and disposing of material. The lower cost being the dredging of soft sediment and disposal at a local site and the higher cost being for dredging hard material and transportation some distance from the dredge site to the disposal site. It is estimated that the disposal of material accounts for between £1 to £10 of this cost per cubic metre of material. If a site is available for habitat creation near to the dredging area there is scope for a reduction in cost of disposal of material.

- Habitat Creation Costs

Habitat creation construction costs vary considerably and depend on such factors as access to the site, distance between dredging location and disposal site, dredged material and foundation characteristics, energy regimes, cost of protective structures, availability of equipment, and local labour rates. Examples of costs for habitat creation using dredged material are shown in Appendix D. It can be seen from an example of saltmarsh creation in Texas, U.S.A. how variable costs can be, depending on the amount of equipment and work needed. The costs varied between $48 and $242 per linear metre, for a marsh which was 20m wide. The marsh was developed in moderate to high wave energy environments, therefore the degree of protection needed, which contributed significantly to the cost element, was variable throughout the site.

Costs can be significantly reduced by allowing natural colonisation of a habitat rather than developing a planting scheme which is expensive both in terms of labour and purchasing the plants or seeds. Costs for simply placing dredged material to elevate a shallow bottom and allowing natural growth of emergent marsh, can be as little as $1.50 to $3.00 per cubic metre.

Costs for creation of dredged material islands also vary depending on the degree of shelter available. If temporary breakwaters are required this may increase the cost significantly, as in the example of island creation in North Carolina, U.S.A. Mudflat creation is relatively cheaper than other habitats as there is no need for planting or construction equipment. Costs for mudflat creation can be as inexpensive as $3-4 per cubic yard, as shown in Appendix D.

The costs involved in establishing a site for beneficial uses of dredged material are based on many considerations, and are usually very site-specific (U.S. Army Engineer Waterways Experiment Station, 1978). In determining such costs, the four phases to consider are planning and design, construction, propagation (if required) and post-construction monitoring and management.

- Planning and Design Costs

Planning and design costs involve site selection, site characterisation, engineering design, and co-ordination. Two dredged material research sites where marsh has been created, have been evaluated by the U.S. Army Corps of Engineers, and their planning and design costs were $45,000 ($5,600/ha) at one site and $35,000 ($4,400/ha) at the other site (1978 prices). Both of these sites were approximately 8 ha in size. The planning and engineering costs of these projects were however elevated as a result of detailed research aspects and difficult site problems. With less detailed research, habitat development should eventually have substantially lower planning and design costs. Both pre-development survey and subsequent monitoring will, however, remain critical if lessons are to be learnt for the future. Planning, design and other requirements are discussed further in Section 3.4.3 (BCDC).

- Construction and Planting Costs

At the two sites discussed above, construction costs, exclusive of dredging were $288,000 ($36,000/ha) and $167,000 ($21,000/ha). These costs included levee construction and maintenance, post construction grading and elevational changes, and other site preparation measures.

Propagation is sometimes necessary if there are no sites nearby for seed supply or the supply of seed from adjacent sites is not adequate. Costs will also vary depending on the species of plant(s) required, whether seeds or shoots are used, distance of transportation, collection and planting techniques, need for shelter during stabilisation of vegetation and other factors. Propagation costs will be extremely site specific reflecting the many variables.

Post-monitoring and management of the site is also a very site-specific cost, which needs to be ascertained at the planning stage of the project. It is important, however, that post-monitoring work is carried out thoroughly in order to determine the relative success of the project. Monitoring requirements are discussed further in Section 5.2.

3.3 Technical Considerations

3.3.1 Feasibility of Using Dredged Material for Habitat Creation

The feasibility of creating habitats using dredged material depends on the technical requirements of each habitat and the biological, chemical and physical nature of the material to be used. The key issues concerned with habitat creation are to provide the optimum amount, type and spacing of food, water and shelter for the species or communities of animals desired. The majority of species/communities have strictly defined habitat requirements, which it may or may not be possible to successfully create and colonise.

The cyclical nature of maintenance dredging activities may lead to problems or opportunities for habitat creation, dependent upon the type of habitat which it is hoped will be achieved. If the aim of the project is to periodically use the dredge material in one creation site as it becomes available, then an opportunistic community which is amenable to disturbance will prevail, and it is unlikely that successionary stages will develop. This type of community may become more valuable/desirable in terms of nature conservation if a valuable successional stage with which it is associated can be maintained through careful management of placement of dredged material.

Opportunities also exist for the one-off use of maintenance dredged material to create a habitat. One example of this may occur when material is needed to raise the elevation of a site to a suitable level for marsh development which can then be self-sustaining. Subsequent (smaller) placings of material may be required where natural deposition is not at a rate high enough to sustain marsh development.

Given the suitability of the nature of the sediment available, a good indicator of whether or not it is feasible to attempt to establish a particular habitat in any one location is whether that habitat occurs elsewhere in the vicinity. Adjacent habitats provide the stock for the natural colonisation of plants and animals. If the habitat to be created was previously present at the site, it is essential to establish why it failed and whether it is feasible to try to restore this habitat. A general observation to make is that coastal habitats occur only where they do because of certain conditions favourable to their well being (Holloway, 1976). Each situation has its own set of physical and biological characteristics that must be considered before, during, and after the dredging and disposal operation, to ensure that all requirements are met for successful habitat establishment (see Section 3.4).

The past success of habitat creation and restoration schemes, the majority of which have been carried out in the U.S., has shown that it is feasible to create and restore many habitats, particularly using "clean" dredged material (see Appendix D). These habitats have been successfully colonised and have, in certain cases, also developed into viable commercial uses.

3.3.2 Physical Characteristics

When considering habitat creation in a particular location and using a particular type of dredged material, various physical parameters must be assessed in order to determine the feasibility of habitat development. These are listed in Table 3.3.2 below.

Table 3.3.2 Physical Criteria Determining the Feasibility of Habitat Creation

Sediment	Sediment type and availability, and the site specific transport regime will be key factors in determining both the technical viability of types of habitat, and their long-term sustainability.
Waves	Coastal habitats in exposed, high wave energy environments may require protection (e.g. a breakwater, peninsula or similar).
Tidal Currents	Knowledge of tidal currents is essential in determining sediment transport regime. Tidal prism at a site is important because it enables the exchange of waters and hence sediments, fauna, seeds etc.
Surges	Important in determining extreme high water levels.
Elevation	Elevation controls the type of coastal habitat which can be sustainably developed at a site, as different habitats depend on different periods of inundation. Dredged material might be used to achieve the correct elevation.
Slope	Slope controls drainage which is essential in maintaining a healthy habitat.
Site Size	Site stability and ecological diversity will both benefit from the largest possible size, particularly if the site is isolated from other similar habitats.

3.4 Habitat Creation

3.4.1 Introduction

The concept of habitat creation using dredged material is relatively new in the U.K. in comparison to the work carried out in the U.S.A. There are, however, many potential benefits to be gained from the use of dredged material, both in economic and environmental terms.

In order to overcome the problem of dredged material disposal in the U.S., and, to benefit wildlife as mitigation for habitat loss due to development pressure, the Army Corps of Engineers (USACE) has worked to develop beneficial use concepts that identify ways in which habitats can be created

The Corps of Engineers are involved at an international level with scientific information and technology interchange in this area, and as such, have an extensive research and development database on the environmental aspects of dredged material disposal, including test and evaluation procedures and protocols and regulatory frameworks.

Habitat creation and restoration has been proved as a viable use for dredged material. Table 3.1.1 outlines examples of beneficial uses of dredged material. As much of the literature reviewed for this study was based on U.S. Army Corps experience, most of the examples are taken from the U.S. There are also some examples from the U.K. but the list is not intended to represent a totally comprehensive review of initiatives.

3.4.2 Sub-tidal Habitat Creation

- Reefs

Various opportunities exist for sub-tidal habitat creation using dredged material. Reefs can be created to enhance fish habitats and benefits can be gained for the fisheries in these areas. An example of such an initiative, although not using dredged material, are the artificial reefs created in Poole Bay, Dorset. These reefs were constructed using industrial waste from local industry. The initial colonisation of the reef was rapid. Small shoaling fish collected around the blocks within a hour of deployment. Since then shoals of fish have been regularly seen around the reef units (The Dock and Harbour Authority, date unknown).

- Gravel Bar

Several uses can be found for sandy or silty dredged material both in terrestrial and aquatic environments. It is sometimes necessary, however, to dredge areas of coarse grained sediment, (e.g. gravel). Gravel can be placed in flowing water to create shoals or bars, and has been used to create trout habitat, to accelerate biological recovery in streams modified by channel development and to increase water velocity and provide substrate for invertebrates. Habitat creation techniques in large waterways are fairly simple, operationally feasible, and should be considered when appropriate material and a suitable site are available (U.S. Army Engineer Waterways Experiment Station, 1988).

A gravel bar was constructed in the Ohio River, near Kentucky, U.S.A., in 1983 as mitigation for the accidental dredging of part of a mussel bed, and its development was monitored. This project concluded that coarse gravel can be placed on sand substrate at suitable sites in large rivers to provide colonization sites for aquatic organisms. Permanent habitats with a variety of substrate particle sizes, ample food supply, and suitable current velocity are necessary to develop a diverse and dense community of aquatic organisms. Gravel bars placed in carefully selected sites are capable of providing such habitat. They can be constructed in less than a week, depending upon quantities of material required, for less than $20,000. These habitats can be considered to offset potential adverse effects of maintenance dredging or as water resource development projects. In addition, they provide an opportunity to evaluate short and long-term effects of habitat construction using coarse-grained sediments (U.S. Army Engineer Waterways Experiment Station, 1988). Potential opportunities also exist for the creation of gravel bars in stable saline environments, providing habitats for settlement of organisms favouring hard substrate for attachment purposes.

- Berms

In the U.S., as in the U.K., large quantities of dredged material are presently being transported many miles to offshore sites. This results in significant costs and makes the material unavailable for beneficial uses. One such alternative use for this material, developed by the U.S. Army Corps of Engineers, however, is the building of underwater berms, often in areas closer to the shoreline than the disposal sites.

Amongst the potential benefits to be gained from these berms are controlling shoreline erosion via the subsequent deposition of material on the shore, and benefits for fisheries due to the topographic irregularities which are created on the ocean floor, enhancing fish habitats.

There are two approaches to the construction of underwater berms - the feeder and stable approaches. The feeder approach involves relatively shallow water placement where the material could move toward the shore. The stable approach involves placement in deeper water less subject to waves and currents (Langan, 1987) and relies on the relatively permanent nature of the placed berm.

The primary benefit of feeder berm placement in practice has been to add sand to the nearshore zone so that it can potentially help reduce erosion of nearby beaches. In many cases, dredging costs can be reduced because nearshore sites are generally closer to the navigation channel to be dredged. A stable berm would be a significant, relatively permanent, bottom feature, that could dissipate storm waves and thus contribute to a reduction in shoreline erosion rates. These berms also provide habitats for fish and other marine fauna.

- Clam and Oyster Flats

Further possibilities for the use of dredged material for the benefit of fisheries have been exploited in the U.S. where there are examples of clam and oyster flats, constructed using dredged material, which have been successfully colonised naturally (Smith,1976). This use of dredged material has enormous potential for use in the U.K.

Table 3.4.2 below summarises sub-tidal habitat creation opportunities and their critical parameters.

Table 3.4.2 Sub-Tidal Habitat Creation Initiatives

Habitat	Environmental Value	Critical Parameters
Topographic bottom features	Fish/shellfish "refuge"	Not enough known to target species for conservation
Eel grass beds (Zostera)	Precursor to saltmarsh development; encourages siltation	Sediment supply; waves/currents
Nearshore Berms	Benthic habitat; breakwater function	Grain size; consolidation and settlement; littoral drift characteristics
Feeder Berms	Beach recharge	Onshore migration; drift characteristics
Oyster beds	Commercial value	

Source: Posford Duvivier 1991

3.4.3 Intertidal Habitat Creation

i) Marsh Creation

The destruction of saltmarsh sites, primarily due to development within the coastal zone, and the awareness of the ecological importance of these diminishing habitats for floral diversity, fisheries and roosting birds, has prompted interest in methods to enhance degraded marshlands and create new sites. Saltmarshes, as well as being an important wildlife habitat, provide a valuable coast protection function.

One potential role of dredged material in the creation of saltmarsh habitat is to provide a suitable substrate for growth of saltmarsh vegetation where such substrate does not already exist. Dredged material may also be used to raise the elevation of the land to a level suitable for saltmarsh creation, to create a slope at the correct angle to receive the required amount of tidal inundation and to increase the area available for saltmarsh development. Dredged material could also be used beneficially by placing it at a calculated distance from the saltmarsh to either provide suitable protection against wave erosion or to feed the saltmarsh with sediment as described in Section 3.6.2.

In order to successfully restore or create a marsh, an understanding of the physical processes is essential. In particular, the hydrological regime, the site topography and soils represent the physical environmental characteristics to which the vegetation and wildlife must adapt.

Habitat goals may also fall within tight specifications depending on the habitat to be created. Factors which need to be considered in this respect include desired vegetation (species, abundance, diversity) and faunal characteristics. Adjacent habitats are critical to establishing both native flora and fauna which are known to survive in the particular location, and providing a supply of seeds, invertebrates, etc. Similarly, although the sediment infauna is not always discussed when talking about saltmarsh development, it is however a vital stage in rendering the habitat suitable for pioneer vegetation. Finally, if vegetation is to be planted, it is important to ensure that the species introduced is a native species and not one which will become so well established that it out-competes other species present. In addition to these factors, flood protection, navigation, access for construction and maintenance must be included in the design process. Table 3.4.3a provides details of the physical and biological requirements necessary for the development of saltmarsh.

Creation, restoration or enhancement of saltmarsh wetlands requires that many design criteria be inter-related. The most effective way of achieving this is through the development of a marsh enhancement plan that determines the design, operation, and maintenance demands of the marsh. In developing this plan, a number of functions or potential functions of the hydrologic system have to be considered. These are outlined in Table 3.4.3a.

There are very few examples of saltmarsh creation in Britain, but there are several examples of restoration schemes. A recent example of proposed saltmarsh creation in the U.K. is currently being carried out at Northey Island, Essex. An area of low-lying land which was protected by an embankment has been allowed to flood periodically by incoming tides following removal of part of the embankment. It is hoped that natural colonisation of this area by saltmarsh vegetation will occur when conditions are favourable. Various restoration schemes have been carried out, particularly in Essex, where sea level rise is threatening coastal habitats. Efforts have been made to protect areas of saltmarsh and planting of saltmarsh plant species has occurred in certain areas, with various degrees of success.

Table 3.4.3a Physical and Biological Requirements of Saltmarshes

Sediment size	The sediment size of the dredged material is important in determining plant species establishment and growth. In general sediment necessary for saltmarsh development should be a combination of silts and fine sands. Sediment size will also influence the stability of the site following placement of dredged material.
Elevation	Initial development between MHWN and MHW (Beeftink, 1977) may be critical to ±30cm. Contouring of topography will provide suitable elevations for most saltmarsh species (Zedler, 1984). Sedimentation should lead to development of upper saltmarsh and a transition through to terrestrial habitats.
Slope	1-3 degrees, relatively flat, reflecting the conditions under which marsh sediments are laid down. Steep and/or concave slopes will reduce the scope for (e.g. the width of) saltmarsh development. Adequate drainage is also important as the impoundment of water may prevent vegetation growth.
Salinity	5-38 parts per thousand (Beeftink, 1977). Lower salinities will lead to invasion by brackish and freshwater species.
Sediment Regime	Sufficient sediment in suspension to allow accretion to occur at a rate of between 3-10mm per annum (Beeftink, 1977). Accretion in excess of 25mm per annum could lead to smothering of some plants, particularly pioneer species.
Waves	More exposed sites will require protection from wave attack particularly while young seedlings become established. UK literature suggests that fetch should be less than 2000m for initial colonisation of saltmarsh (Boorman, 1987). A mudflat or similar breakwater fronting the saltmarsh is important in reducing direct wave attack.
Currents	Must be sheltered site. Good tidal circulation is, however, essential.
Importance of adjacent habitats	Very important for provision of a seed bank for colonisation. Also a good indication of where a saltmarsh can grow. If saltmarsh is nearby it shows that conditions are or were generally acceptable.
Planting	Width of planting should be greater than 6m if marsh is to become self-sustaining.

Source: Posford Duvivier 1991

In the United States, however, an extensive programme of saltmarsh creation and restoration, using dredged material, has been undertaken because of the requirement for mitigation in the form of habitat creation if a proposed development will damage an existing wetland habitat (see Appendix D). In 1988, the San Francisco Bay Conservation and Development Commission (BCDC) reviewed the successes and failures of fourteen mitigation projects involving habitat creation, mostly saltmarsh, and concluded that four factors were of particular importance in cases where marsh restoration was judged successful. These lessons apply equally to the use of dredged material for the development of saltmarsh habitats:-

- The site elevations achieved were suitable for the desired habitat.
- The site was adjacent to an existing "source" of flora, fauna, etc.
- Water circulation objectives were achieved and water quality was satisfactory.
- The site had been the subject of careful planning and detailed design by suitably qualified personnel.

Suitable soil conditions, successful planting, and a requirement for ongoing monitoring and maintenance were also cited as contributing to successful projects.

Among the reasons given for the total or partial failure of projects were the following:-

- The project had simply not been completed.
- Problems with soil chemical composition or with soil structure (e.g. soil had been compacted during construction).
- Poor planning or unauthorised modification of the approved plan.
- The site elevation achieved was not suitable for the desired habitat.
- Adverse impacts of man (i.e. disturbance by all-terrain-vehicles, recreationalists, pets, etc.).

The lessons from the BCDC report are equally important in the British context, particularly given our relative lack of experience in creating "new" saltmarsh.

ii) <u>Mudflat Creation</u>

Mudflats provide a valuable coastal habitat particularly for the overwintering and migratory birds which they support. Concern is often expressed as to the loss of mudflat area due to coastal development. An example of mudflat loss occurred in the Tees Estuary where over 80% of the intertidal flats have been claimed for agriculture, industry and ports since 1970 (Davidson et al, 1991).

British experience in the creation or restoration of mud or sand flats is minimal. The U.S. Army Corps of Engineers have, however, carried out mudflat creation schemes using dredged material to create habitats for birds using underwater placing of material to raise the level of the seabed. The main problems encountered in this operation have been littoral drift causing sediment loss and, in sites which were exposed to high wave energy, erosion. In the latter case rip rap breakwaters have been placed to reduce wave energy and promote stability.

Another example is provided where the U.S. Army have successfully created intertidal flats by pumping dredged material onto a rocky beach. Commercial clam and worm beds colonised the site naturally. This was a cheap and effective use of dredged material which resulted in the establishment of a commercially viable habitat. It is important however in this sort of example that the site for dredged material placement is not of existing value as a habitat in its own right.

Other examples of mud/sand flat creation are given in Appendix D.

Mudflat creation using dredged material is proposed in France as a mitigation for habitat loss in the Le Havre Estuary. The stability of the created mudflat appears to be very sensitive to velocity. Velocities in the range of 0.5-0.7 m/s are being promoted to avoid excessive erosion while minimising the chance of accretion leading to colonisation by pioneer saltmarsh species (Cellule de Suivi du Littoral Haut Normand, 1989).

There is limited available information on the physical and biological parameters for mud or sand flat development as this particular habitat has not been as extensively studied as, for example, saltmarshes. The information which does exist has been collated in Table 3.4.3b.

Table 3.4.3b Physical and Biological Requirements of Mud or Sand Flats

Sediment size	The sediment size distribution of the dredged material will determine the stability and cohesiveness of the mudflats and the rate of settlement of material.
Elevation	Below MHWN
Grade	Site specific. Little information available.
Salinity	N/A.
Sediment Regime	Site specific. Clearly important but little information documented.
Waves/Currents	Site must be protected to allow deposition of sediment and ensure minimal erosion. Related to sediment regime. Site specific understanding required.
Importance of adjacent habitat	Must be close enough for faunal colonisation.
Velocity	Velocities of 0.5m/s to 0.7m/s are suggested in Cellule de Suivi du Littoral Haut Normand, 1989.

Source: Posford Duvivier, 1991

3.4.4 Dredged Material Islands

Mitigation for the loss of bird feeding areas in the United States has led to the creation of dredged material islands. On the south Atlantic and Gulf Coasts, the Corps of Engineers have used dredged material to create a string of artificial islands and set them aside as wildlife refuges. They have had tremendous success with these areas both as nesting sites and as stopovers and wintering areas for migratory waterfowl (U.S. Army Corps of Engineers, Date unknown).

Construction of new islands for birds and other forms of wildlife is technically and environmentally feasible. One example documented (U.S. Army Corps of Engineers, December 1986) describes two islands constructed in Core Sound, North Carolina, for habitat development. The islands were retained by the use of large sand-filled nylon bags, and were designed so that, during future maintenance dredging of the nearby navigation channel, material could be added within the original sandbag retainers and more sandbags could be added to provide higher retention dikes. These islands were placed in an area with adequate shallow water and food resources but with a scarcity of bare-ground nesting habitat. The islands were used by nesting terns and skimmers during the first breeding season after construction. The physical and biological parameters necessary for the construction of dredged material islands are documented below in Table 3.4.4.

Table 3.4.4 Physical and Biological Requirements for Bird Islands

Elevation	Ideally 1m to 3m above MHW to prevent flooding of areas used for nesting while also reducing the risk of wind erosion.
Grade	Steep sides should be avoided.
Size	2 ha to 20 ha have been recorded.
Salinity	N/A.
Sediment Regime	Coarse materials (sand and shell) provide bird nesting substrates.
Location	Isolated from predators and human disturbance. Adequate food resources.
Timing	Build in autumn/winter in preparation for breeding season.

Source: Posford Duvivier, 1991

3.4.5 Terrestrial Habitat Creation

The option of land-based disposal for habitat creation provides a viable use for dredged material. There are certain advantages of land-based disposal, these are outlined below:-

- Adaptability.
- Creation of biologically desirable habitats.
- Elimination of problem areas by restoring wastelands.
- Low-cost enhancement or mitigation.

Terrestrial habitat development will usually add little to the cost of disposal operations. Standard procedures may involve liming, fertilizing, seeding, and mowing. It may also be necessary to reduce the salt content of the material to be used for terrestrial habitat development as many species of terrestrial fauna and flora will not tolerate material of high salinity.

There is potential however for public opposition to disposal if the site is to be used for long-term disposal of dredged material. This may be overcome by the clear identification of future plans prior to habitat development (U.S. Army Corps of Engineers, Date unknown).

It is often the case that dredged material disposal sites are rendered as wastelands, unsuitable for building due to soft foundations or not capable of supporting vegetation because of toxic properties or sterility. Turning these sites into wildlife habitat by modifying the soil properties and establishing vegetation is an opportunity for positive benefits for nature conservation.

If a decision for terrestrial disposal using dredged material is made, certain considerations must be taken into account. These include:-

- Chemical and physical sediment characteristics (e.g. nutrient levels, and concentration of contaminants, heavy metals, or salts (see Section 4)).

- Sediment size distribution is an important factor in the development of terrestrial habitats as it determines the water content of the sediment. If the sediment is predominantly sandy, the sediment will lose its water content rapidly and will generally have a low nutrient content. Finer-grained sediments are usually easier to vegetate but require months to dry out to a usable level. Grain size also influences the association of contaminants with sediment.

- Site evaluation - A proposed site for habitat creation should be evaluated as to its current nature conservation interest (see Appendix C).

- Determination of habitat goal - this will involve assessing local and regional characteristics and wildlife needs (see Appendix C).

- Selection of appropriate plant species to meet the desired habitat goal.

3.5 Aquaculture

3.5.1 One concept with a high potential for obtaining new sites is aquaculture. The concept is documented in a USACE Information Exchange Bulletin (August 1991). Aquaculture is promising as a compatible activity with dredged material disposal due to the similarities in design characteristics between dredged material containment areas and aquaculture ponds. There are important aquaculture industries for oysters, clams, crayfish, catfish, trout, bait fish and ornamental fish and shrimp farming which is rapidly expanding in the international aquaculture scene. Another commercial aquaculture enterprise that has potential for use in dredged material containment areas is shellfish culture, including mussels and clams. Another species with potential is striped bass.

There also appears, therefore, to be the potential for research to determine whether these initiatives could be developed to provide viable commercial uses of dredged material containment areas for species cultivated in the U.K.

3.5.2 Studies carried out in the early 1970s indicated that shrimp grew well in experimental ponds in which dredged material had been placed. A three year project in shrimp cultivation was conducted to establish the economic and technical feasibility of containment area aquaculture. The project involved growing penaeid shrimps in two active dredged material containment areas. The results of this project revealed that no adverse affects from the dredged material were evident and the prawns were successfully cultivated in the containment ponds.

Future prospects for dredged material containment areas include, in cold water areas, commercial aquaculture facilities for rainbow trout and salmon. Various species of salmonids can be produced in either freshwater or saltwater. Under current production practices these are usually grown in cages rather than in ponds. However, production practices for these salmonids are evolving and pond culture remains a possibility.

3.6 Beach Nourishment

3.6.1 In attempts to combat coastal erosion, various remedial measures may be put in hand, ranging from a vertical sea wall to a rock rubble slope. A solution which has more aesthetic appeal is beach nourishment.

Beach nourishment, or the placing (by man) of material along the coast to augment sand washed away by erosion, is routinely carried out by the U.S. Army Corps of Engineers in New York, Florida and other areas. In the U.K., beach nourishment is less widely used, but examples do exist of such schemes as shown below.

3.6.2 <u>Criteria for Carrying Out Beach Feed</u>

In general terms, coastal sand is transported offshore during winter storms and back onshore in calms. A healthy beach profile is one that can accommodate these movements. Sand dunes may well form by the deposition of sand above high water mark behind such beaches and the colonisation of this sand by pioneer sand dune species can follow. This equilibrium however, is easily disturbed. Where beaches and dunes disappear, it is clear that something must be done if the dune system is to be safeguarded and the beach preserved for recreational purposes.

One of the most economical and environmentally acceptable methods of protection is to replenish the beach by pumping sand ashore. As well as providing a benefit to recreational users of the beach, beach feeding can also be beneficial for nature conservation by providing a source of material for eroding dune systems. The requirements for such an operation are set out below.

When beach feed is undertaken, large volumes (tens of thousands of cubic metres) of material are generally involved. If the material is sourced specifically to provide the beach feed, then the total cost of the operation can be high. If the beach replenishment can take advantage of the material made available by local dredging operations then the cost of replenishment can be reduced. The feasibility of this does, however, depend upon the available material satisfying various criteria in respect of its intended purpose as beach replenishment. In the case of Poole Harbour, for example, most of the material dredged from the capital dredging of the Swash Channel was used for beach nourishment by Bournemouth Borough Council and there was no tight specification imposed on the material supplied.

Generally however, there are various criteria which should be addressed when planning beach nourishment. These include, but are not necessarily limited to the following:

- function
- coastal processes - sediment retention properties (e.g. mobility/particle size)
- effect on downdrift situation
- environmental conditions
- cost
- necessity for subsequent recharge

These criteria are discussed in more detail below.

i) **Function**

The beach feed must satisfy the function for which it was intended, (e.g. to provide a recreational beach; or to provide a sea defence; or to regenerate a saltmarsh etc.). This criterion largely dictates the "type" of material (sand, shingle, mud) which might be acceptable.

ii) **Coastal Processes**

The coastal regime should be thoroughly investigated before beach feed is undertaken. This will entail studies of the following parameters:

■	wave climate	wave heights, periods, directions and duration.
■	currents	magnitude and direction
■	longshore transport	under average conditions and during storms
■	onshore - offshore transport	an appreciation of the effect of this on beach profile and of the impact of net offshore losses.

The factors listed above, together with the particle size distribution of the beach feed material, determine its retention properties. That is, the mobility of the material and the likely rate of loss (from the site of placing) due to drift either alongshore or offshore. Generally, small particles are more mobile than coarse particles (eg. sand compared with shingle).

Depending upon the circumstances, it may be necessary to incorporate some means of reducing losses, for example by the use of groynes or offshore breakwaters. These, in turn, require very detailed consideration in order to achieve the required function and level of performance.

iii) **Effect on downdrift situation**

Consideration should be given to the downdrift effects of the proposed beach feed. Often the effects will be beneficial in that downdrift beaches will be fed by the longshore transport. However this is not necessarily the case as the deposition of material could also result in the unwanted siltation at wharfs or channels, or the smothering of intertidal and benthic habitats. On the Lincolnshire coast, for example, concern was expressed regarding the proposed beach nourishment works between Mablethorpe and Skegness, that the material used for the beach nourishment, or the fines which escape during nourishment, will be transported down to Gibraltar Point (south of Skegness). Gibraltar Point is a National Nature Reserve and concern was expressed that the sediment moving down to Gibraltar Point may smother intertidal communities and that any difference in size and chemical composition of sediment may cause a detrimental impact on the coastal habitats/communities. Stringent monitoring will therefore take place and, if unacceptably high losses of material are recorded leading to detrimental environmental change, controlling structures will be introduced.

iv) **Environmental Conditions**

As indicated above the effect of smothering benthic invertebrates should be considered both during the placement of material and as a result of the potential effect of turbidity generated by offshore transport of fines from imported material (see also Section 2.1.4 and 2.1.5).

v) **Cost**

The cost of beach feeding is dependent on several factors including

- scale: in dredging, as other fields, the cost depends on the extent of work carried out. Plant mobilization costs are high.

- haul distance: costs are greatly reduced if the feed material is won near the dumping site

- method of dumping: costs will depend on the method of deposition for the feed material that is dictated for a particular site. The costs of deposition can be quite different for material dumped by bottom opening barges than for material hydraulically pumped ashore

- downtime in bad weather: in exposed locations dredgers will not be able to work as efficiently during inclement weather. Bad weather can stop production

- grading: the degree of grading of the feed material required

- the nature and source of the feed material: the nature of the feed material together with its source will strongly influence the type of dredger and equipment that is suitable for carrying out the work (see Section 2.1.2)

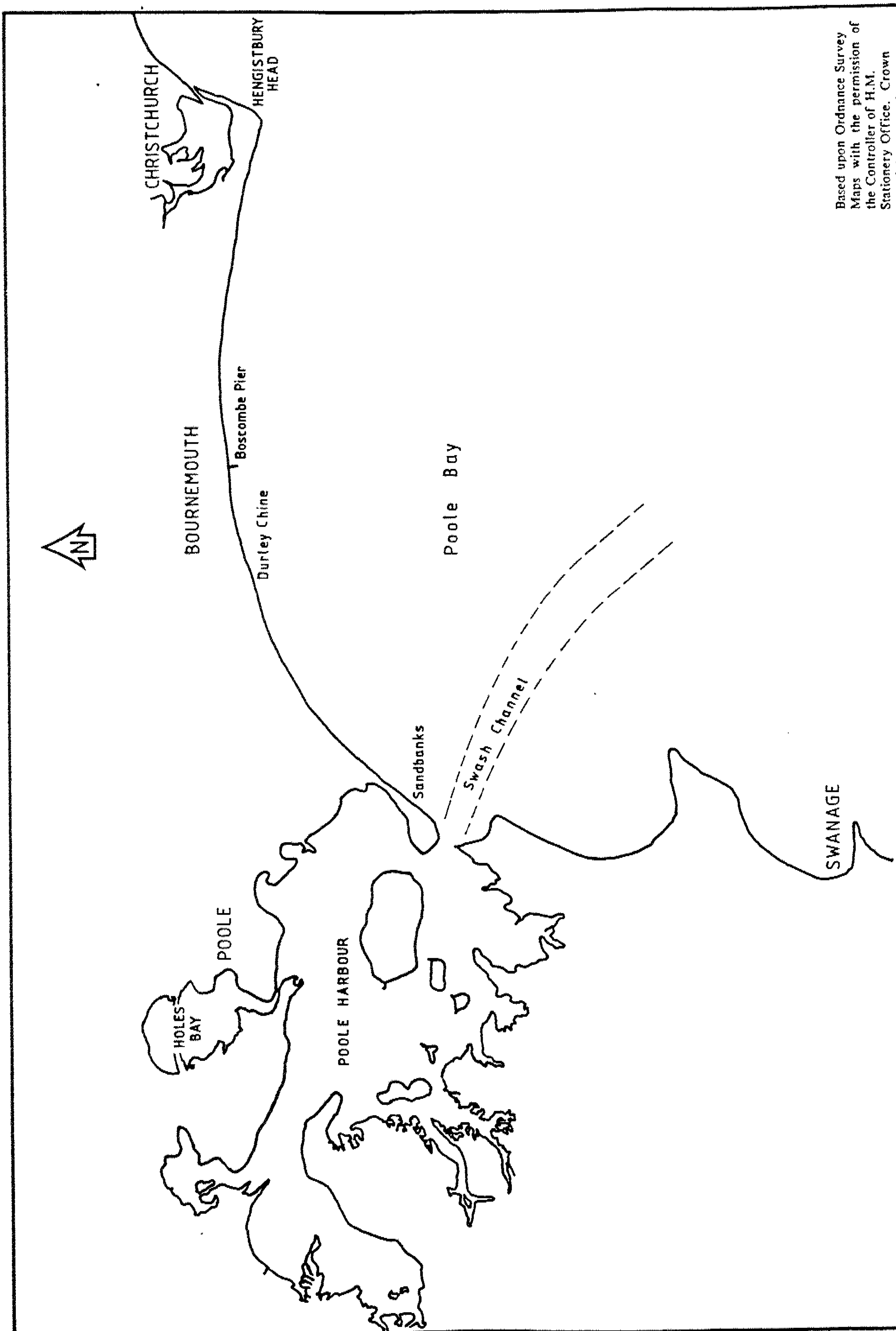
vi) **Necessity for Subsequent Recharge**

With many recharge schemes there will be a gradual loss of material downdrift therefore periodic recharge may be necessary. Consideration would have to be given as to how often this will be necessary considering the costs and implications.

3.6.3 Poole Bay

Beach nourishment has provided a solution to the coast protection problem on the beach at Bournemouth, in Poole Bay, Dorset (see Figure 3.6.3), on the south coast of England. Because of its situation relative to the prevailing south west winds, the beach between Poole Harbour entrance and Boscombe Pier is well protected from direct wave action by the headlands at Swanage and Anvil Point, but further east the degree of exposure to waves is reduced and the Hengistbury beach suffers significant draw-down during storms.

In 1970, a trial beach replenishment scheme was put in hand by the local authority, which involved the dredging of some 90,000 m^3 of coarse sand from several kilometres offshore. This sand was dumped in the near offshore zone, and subsequent surveys found that the beach zone was raised overall by 0.26m, nine months after the scheme.



Title **POOLE HARBOUR AND BOURNEMOUTH BEACH**	CONSULTING ENGINEERS **POSFORD DUVIVIER**	DATE FEB. 92	SCALE 1:100,000
		DRAWN J.R.	CHKD
		Figure 3.6.3	

Following the success of the 1970 trial, a major scheme to build up the beach frontage from Bournemouth Pier to Solent Road was commenced by Bournemouth Borough Council in July 1974. The cliff area which fed the beach was stabilised by drainage, grading and planting. This led to a deterioration of the beach to such a degree that it was no longer effective and certainly not acceptable as a sea defence (Newman, 1978). Bournemouth Borough Council therefore increased their efforts to stem coastal erosion, by using capital dredged material from the Swash Channel for beach nourishment (see Section 3.6.2)

3.6.4 Suitability for Nearshore Injection for Trickle Feeding

A wide ranging programme of research has failed to identify any deliberate successful trickle feeding schemes. The aim of this technique, however, is to increase the area of a saltmarsh by dumping a mud bank offshore and allowing the marine climate to gradually feed the marsh from the mud bank.

The parameters which affect onshore/offshore movement are shown below in Table 3.6.4.

Table 3.6.4 Parameters Affecting Onshore/Offshore Movement of Material

The diversity of the sediment material.	- the less dense the material the more likely it is to be transported.
The particle size of the sediment material.	- the smaller the particles the more likely they are to move.
The maximum water velocity near the bed caused by a wave.	- the greater the velocity the greater the movement of material
The friction factor.	- a factor which takes account of the difficulty in releasing a particle from the seabed mass. Until this friction is overcome there will be no movement.
The Ursell Number.	- this number is defined as: $\frac{\text{Waveheight} \times (\text{Wavelength})^2}{(\text{Waterdepth})^3}$ The greater the Ursell number the more likely that transport will be onshore, (ie. helpful to trickle feeding).

The success of this method clearly depends on the criteria mentioned. The wave climate of the site should be mild to ensure that material is moved onshore rather than offshore and so that any material deposited on the saltmarsh remains there and is not eroded in storm conditions. Longshore currents should be small in order that the material is not simply lost from the site and deposited elsewhere, possibly with detrimental consequences. The effectiveness of the method relies upon the placed material being transported onshore over a timespan such that the rate of shoreline accretion satisfies the functional requirements, (e.g. desired rate of marsh development, criteria for plant development, etc.). The rate of onshore transport is difficult to calculate with confidence, especially given the nature and mechanical properties (particle size, cohesion etc) of the material forming the source. Given also the paucity of previous field trials in this area it follows that planning and design studies should focus on establishing that the material will actually move onshore, with realistic (broad) tolerances being allowed in the quantification of rates.

3.6.5 Merits of Sediment By-pass Schemes Where a Dredged Channel Crosses a Longshore Drift Route

Major changes in a beach regime, such as dredging a channel or constructing a breakwater, can cause significant effects downdrift as discussed in Section 2.1.8. A scheme which allows the sediment to bypass the obstruction can therefore be beneficial in that it restores the sediment transport to the downdrift side.

In Poole Bay (see Figure 3.6.3) there is generally a net transport of material from west to east, although a westward drift exists between Durley Chine and Poole Harbour. Placing of the materials won from the Swash Channel onto Bournemouth's beaches therefore helps to restore the loss due to longshore transport. This is not, however, a sediment by-pass in the true sense.

An example of such a sediment by-pass operation occurs at Shoreham, Sussex, where the breakwaters together with the dredged channel into the harbour prevent movement of shingle across the harbour entrance. Accretion of shingle on the west side of the harbour together with severe erosion on the downdrift side had become very apparent. A timber and concrete groyne system was therefore constructed downdrift and shingle was then excavated at intervals from the beaches west of the harbour and taken to be dumped downdrift of the harbour entrance.

Parameters critical to sediment bypass schemes are shown below in Table 3.6.5.

Table 3.6.5 Parameters Critical to Sediment Bypass Schemes

The rate of longshore transport.	- the volume of material that in a given time span passes a given line. Clearly the longer the rate of longshore transport the more worthwhile a sediment bypass scheme may become.
The effectiveness of the dredged channel as a trap.	- the more effective the trap is, the greater the amount of material caught in any period and the more worthwhile the sediment bypass scheme will become. Clearly the wider and deeper a channel is the more effective a trap it will become. Similarly the particle size and density of the material transported is a factor in that larger, denser particles will more readily fall into the channel and be lost to the longshore transport system. Small light particles can more easily be carried over the channel trap.

3.7 Other Beneficial Uses of Dredged Material

3.7.1 Aquatic Uses

In addition to the above uses, other examples of aquatic or wetland beneficial uses of dredged material for nature conservation include the use of a created wetland as a stormwater retention basin or to improve the quality of stormwater runoff or sewage effluent, and the use of sediment as fill for aggregate dredging sites to prevent slumping and to replace lost habitat.

3.7.2 Upland Uses

Some land-based disposal areas have been leased to farmers, who have been successful in using them as crop and pasture lands, while sites in or near cities have been used as industrial sites and parking areas. The Corps of Engineers is also working on better ways to manage upland disposal sites for maximum use and to extend the lives of these areas. Once the site is filled, potential uses for the land area are increased through a better load-bearing capacity of the dewatered dredged material. Craney Island, a large containment facility in Norfolk, Virginia, known as a haven for wildlife, is an example. Extensive dewatering and other site management techniques were recently used there, and the useful life of the site as a disposal area was increased by over 30 years (U.S. Army Corps of Engineers, Date unknown).