Environmental Management Guidelines, No. 20

ENVIRONMENTAL GUIDELINES FOR

Sand and Gravel Extraction Projects

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

ENVIRONMENTAL GUIDELINES

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2 Irrigation in Arid and Semi-Arid Areas
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Sand and Gravel Extraction

United Nations Environment Programme, Nairobi, 1990

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Foreword

It has been our concern, shared by other bodies and agencies within and outside the United Nations family, that development projects and programmes should take account of basic environmental parameters and constraints. It is clear that broad-based sustainable development is not feasible, especially in the long-term, without sound environmental assessment and management.

There are many pitfalls to be avoided in initiating development activities and many opportunities that can be availed of without much additional cost. Experience during the last ten years has shown that remedial measures must be incorporated, if they are to be effective, in the conceptual and design stages of projects. The same applies to planning procedures. Later attempts may prove to be only cosmetic, as ecosystems are fragile and complex and may not recover from the stresses to which they are exposed.

Prepared by UNEP, in close consultation with the United Nations specialized agencies concerned, the first six guidelines were jointly financed by UNEP and UNDP. They were adopted by UNDP and distributed to the UNDP Resident Representatives. The remaining guidelines in the series have been prepared by UNEP to cover important areas of emerging concern.

The remedial or preventative measures outlined are meant to be illustrative rather than exhaustive in nature: there is no substitute for local experience, foresight and prudence. We have only attempted to draw attention to the kind of considerations which must be kept centrally in mind in undertaking development activities.

The objectives for which we strive in these guidelines are numerous and interrelated, requiring a formidable array of diverse technologies and disciplines. Although the guidelines are essentially national in nature and scope, international co-ordination to bring into play the different inputs required, may often be necessary.

I sincerely hope that the guidelines will be acceptable and meet practical needs, particularly in developing countries. Additional sectors will be examined and further guidelines prepared in collaboration with the UN specialized agencies, UNDP and other multilateral and bilateral development financing institutions, as appropriate, taking fully into consideration comments and advice which we expect to receive regarding this series of guidelines.

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Preface

At an informal meeting held in Rome in September 1978, the Designated Officials for Environmental Matters (DOEM) of the United Nations Administrative Committee on Co-ordination recommended, on the basis of a report prepared by a consultant, Mr. O.M. Ashford, that UNEP undertake, in close collaboration with the UN specialized agencies, the preparation of environmental operational guidelines to assess and minimize the possible adverse environmental impacts of development activities. The report of the meeting states "that priority should be given to the preparation of guidelines aimed at improving the consideration of environmental aspects at all stages in the planning and execution of projects". It was recognized that the level of sophistication in such guidelines would depend on the audience for which they were intended. Much of the available material was of a general nature which would mainly be of interest to universities and senior international and national officials. At the other extreme, detailed guidelines based on in-depth studies of specific projects would be very useful for specialists but difficulties were foreseen in obtaining the necessary information for such analyses, which would take a long time to complete. The meeting agreed that the primary need was for guidelines which would be useful at the operational level. For this purpose each of the major categories used in the consultant's report (e.g. agriculture) would have to be broken down into a number of sub-areas (e.g. crop pest control and rangeland management). A first list of sub-areas on which guidelines should be prepared soonest was agreed to be as follows:

1. Pesticide use on industrial crops
2. Irrigation in arid and semi-arid areas

3. Watershed development
4. Pulp and paper industry
5. Hides and skins industry
6. Coastal tourism

At a subsequent meeting, the DOEM determined that the operational guidelines should "avoid undue technicalities. They should be clear-cut statements of the environmental concerns, parameters and constraints arising in the area of interest. A distinction should be made between what would be useful for informed laymen, such as UNDP Resident Representatives or officials in the Ministry of Planning or Ministry of Economic Affairs of a developing country, to reach a decision on the need for corrective action and nature of the environmental considerations in a given project at a very early stage of its formulation on the one hand, and the analytical tools required by engineers, economists and other scientific consultants in the form of co-efficients, etc., to implement a project on the other. The latter should not be a part of the operational guidelines but be included in manuals of implementation".

In the event, the guidelines that have been prepared vary in the nature of the material assembled and the technical details analysed. This has been done deliberately.

In order to afford an opportunity to assess the practical utility of different approaches to the preparation of guidelines, it was considered necessary to establish models which could be compared and evaluated in terms of practical utility. UNEP would gratefully receive views on the analytical frameworks and approaches adopted in the different guidelines as well as suggestions for their improvement or amendment.

The environmental guidelines in this series are not intended to be prescriptions for corrective action or constraints on the methods, nature and scope of development activities. They are presented in the belief that dynamics and change induced by development aims are not without environmental hazards and risks. It is necessary to identify such hazards and risks where they arise and take early steps, because later attempts at remedial action may be illusory, more costly than preventive action at the outset, and in some cases, may be so costly as to bring into question the overall economic viability of the project.

We acknowledge with gratitude the contribution received from the UN specialized agencies, particularly the Food and Agriculture Organizatiion (FAO), for preparing the earlier guidelines. Without financial assistance from UNDP, the operational guidelines could not have been completed effectively within the time available. We have also been dependent upon the assessment of the Resident Representatives and the Headquarters staff of UNDP on whether the guidelines meet specific needs in the field.

Within UNEP, a number of colleagues have assisted in the preparation and editing of the operational guidelines. I wish to thank in particular Mr. Nay Htun (for the guidelines on the pulp and paper industry and on the hides and skins industry) and Mr. Mohamed Tangi (for the guidelines on coastal tourism). Ms. Merran Van der Tak, Ms. Shahida Chaudhary and Mr. Mark Aeron-Thomas assisted in the research and editing of the first six guidelines in the series; the latest guidelines have benefited from the sustained efforts of Ms. Sophie Schlingemann, Ms. Gill Mayers and Ms Leslie Duckworth!

UNEP's decision, to produce further guidelines, on issues currently on the international agenda for environmental action, has resulted in subsequent guidelines in the series. The first six have been complemented by the following:

7. Formulation of National Soil Policies
8. The Restoration and Rehabilitation of Land and Soils after mining activities
9. Afforestation Projects

10. Agricultural Mechanization
11. Agroforestry
12. Farming Systems Research
13. Environmental Consideration in Rural Roads Projects
14. Domestic Waste water Management
15. Rural Workcamps
16. Flood Plain Management
17. Coastal Protection Measures

The three latest ones are on:

18. Handling, Treatment and Disposal of Hazardous Wastes 19. Fish Farming
20. Sand and Gravel Extraction Projects

On the basis of reports received, additional guidelines are under editorial consideration.

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Introduction

The environmental impacts of sand and gravel extraction are not always readily obvious and hence have long been under-estimated. The cumulative, far-reaching effects of numerous uncontrolled operations have contributed substantially to the degradation of river and coastal ecosystems.

Sand and gravel are won mainly from river bed deposits and from the beach zone, both on-shore and off-shore. Mining changes the physical characteristics of the mining area and disturbs the closely linked flora, fauna, hydrology and soils. Negative effects are not limited to the site itself, but may extend to other parts of the coastal or river system.

To safeguard the future of sand mining and the continued viability of other uses of the resource base, the environmental effects must be controlled. These guidelines have been developed to build awareness of the potential environmental impacts of sand and gravel extraction and to suggest ways in which the environmental degradation associated with the activity can be minimized.

Constraints to the Availability of Sand and Gravel Resources

Sources of sand and gravel will continue to be exploited to supply development needs. Sand is a particularly versatile material with a wide range of specialist uses including glass making and fibre optics. Both sand and gravel are vital for urban and industrial development, and transport infrastructure development, where they are used in cement making and as fill. The increased popularity of beach nourishment (the application of sand to eroding beaches) as a coastal protection strategy in some countries has provided an additional source of demand for marine sand. Silica sand is also mined from beaches, dunes and near-shore areas for the mineral seams it contains. The minerals, chiefly rutile and ilmenite, find a number of uses ranging from aero-engine manufacture to the making of ceramic glazes.

In common with other extractive industries, sand and gravel mining operations represent a major intervention into the physical environment. The potential exists for adverse impacts on the hydrological regime, soils and genetic pool of plants and animals. Nuisance impacts, such as noise and dust creation, may also occur. The range of environmental impacts that often accompanies sand and gravel extraction, therefore, not only makes the activity unpopular - a "bad neighbour" - but can also lead to economic repercussions for other resource users in the vicinity of the project and to a long-term decline in the productivity of the resource base.

Heightened public awareness and appreciation of the value of the wetland and beach and dune environments in which most mining for sand and gravel takes place has focused attention on the growing significance of values which are not considered strictly "economic". These often less tangible values include: use for scientific research, and the satisfaction of knowing that wild, natural areas exist. The stark, complex natural beauty of undulating coastal sand dunes and the peace and tranquility afforded by rivers are also important qualities that are becoming appreciated and demanded by more and more people. Sand dune areas are often major natural attractions, even national monuments, and hence powerful tourism and recreational interests are increasingly resisting attempts by the mining industry to enter these areas. For example, in Australia, a country noted for its extensive network of protected areas, nearly 50% of sand reserves are protected from mining by varius conservation designations.

In the past the "wetlands are wastelands" attitude ensured that sand and gravel extractors could exploit with impunity. Now it is recognized that the materials and the ecosystems they support have an enduring economic value if left in situ. This "ecological" value may exceed the market value of the extracted material, and hence justify the protection of natural areas against encroachment from sand and gravel mining interests.

Unlike most other development activities, the siting of extractive industries is constrained by the location of exploitable reserves. In addition, the high costs of transporting a low value per unit weight material such as sand or gravel dictates that extraction should take place close to the point of use. Successive phases of urban and industrial expansion have resulted in the exhaustion of many river and coastal sand and gravel reserves located within an economic distance of markets. Conservation designations have sterilized many others, further constraining the locational choices of the industry. In addition, natural replenishment of accessible sand and gravel resources is severely restricted in many areas by human interventions in the river and coastal sediment budget, chiefly dam construction, harbour-building and the erection of coastal defence structures such as sea walls and groins. Rising seas have, furthermore, begun to encroach on beaches, sand dunes and sand banks.

Substitute materials are not available for uses requiring pure sand. For construction purposes, however, crushed rock may be equally suitable, and can often be won with fewer major environmental repercussions than coarse sand and gravel. Recycling of glass has the potential not only to conserve finite sand resources and space in waste disposal sites, but also to considerably reduce energy use. However, substitution and recycling will not radically affect the huge demand for sand and gravel.

As exploitable reserves decline, and the public becomes further sensitized to the desirability of protecting the often highly scenic rural locations in which sand and gravel occur, the potential for conflict between mining and other users of the environment is likely to rise. It is clearly vital, therefore, that the environmental destruction associated with the activity is minimized. Environmental safeguards must be built into the planning, design, management and reinstatement phases of all projects so as not to jeopardize other legitimate claims to the shared environmental resource base.

Planning for Reduced Environmental Impacts

The emergency closure of sand or gravel mining projects when environmental impacts rise to critical proportions is a heavy-handed approach to environmental management and one which is economically damaging. Preventative action is far more effective and also makes economic sense. However, environmental concerns are often only considered late in the project cycle. Opportunities for mitigating unwanted effects are then limited to management measures, as the project is too advanced to permit useful discussion of alternative sites which may be more desirable on environmental grounds. At this late stage it is also useless to question the need for the project, or the potential for meeting demand using other materials, such as crushed rock.

The potential environmental impacts of the project should be considered at all stages, from its initial planning to the completion of reinstatement operations at the extraction site. In addition, the resource demands of the project should be evaluated within the context of the needs and constraints of other developments and non-consumptive land uses in the region. All synergystic effects and conflicts with other resource users should be identified prior to licensing of the development. This implies the need for a regional assessment of the capacity of the environment to support resource consuming activities. Vulnerable areas can then be located and unsuitable activities steered into more environmentally robust locations.

Sand and gravel extraction projects may vary in scale, some being so minor as to be considered insignificant in terms of their environmental impact. However, the cumulative effect of many individually insignificant projects is often substantial, and may damage the productive capacity of the environment irretrievably. The environmental significance of a large number of small scale activities should not, therefore, be underestimated.

The proponents of larger developments are often required to carry out an environmental assessment of the proposed development. This is a formal, legislated or informal procedure in which the impacts of the projects on the environment are investigated and reported. The environmental effects of small scale sand and gravel extraction operations should be considered with reference to the carrying capacity of the area and sited accordingly.

The environmental assessments of larger projects often give in-depth consideration to the impacts on the living resources, hydrology and soils on-site and in the immediate vicinity of the site. However, secondary impacts, i.e. those not directly generated by the sand or gravel extraction project, are often deemed to be outside the scope of the assessment and are not considered, even though they may be even more significant in terms of magnitude and effects than those directly generated by the project itself. The project may, for example require the construction of service roads. Road building in environmentally sensitive areas can give rise to a range of negative environmental impacts which may make the project hard to justify. The enhanced accessibility of the mining area may make it irresistible to other activities, which may choose to locate there to exploit timber reserves or wildlife resources. These strategic considerations are most easily addressed from the spatial perspective of the region as a whole.

Balancing the needs of the sand and gravel industry and other claims on environmental resources presupposes an understanding of the range of environmental impacts which may occur. There is, therefore, a need to raise awareness of the environmental constraints of sand and gravel mining activities and to develop expertise in evaluating and managing environmental impacts.

The range of possible environmental impacts of sand and gravel extraction projects is now discussed with reference to the different environments in which these activities take place. Methods to minimize the impacts and mitigate their effects are suggested. Maintenance dredging of waterways is considered outside the scope of sand and gravel extraction, and is, therefore, not considered.

Sand Dune and Beach Sources of Sand and Gravel

Beach and dune systems often contain large reserves of accessible, well-graded sand and/or gravel of marine or cliff origin. Extraction is technically unchallenging and can be effected using earth moving equipment. However, since sandy coastal areas are some of the world's most highly valued landscapes and some of the most physically unstable landforms, conflicts of interest inevitably occur where mining is proposed.

Dune areas can support temperate forests, rainforest, wetlands, shrublands and heath, or they may comprise waves of wind-sculpted bare sand. The unusual and sometimes unique physical attributes of sand dune and beach areas and their associated fauna and flora make them popular candidates for national park designation. Where fragile vegetation communities clothe unconsolidated sandy slopes, any external disturbance, such as intensified grazing pressure, or the stripping of vegetation prior to mining, can trigger wind erosion. Small disturbances can lead to the formation of blow-outs at intervals along the dune ridges. These breaks in the dune face funnel wind-blown sand inland. Once initiated, the loss of sand may be impossible to stop. It is often for this reason that many countries require operators to progressively re-contour and re-vegetate worked out sand mining areas.

Impact: Destruction of Flora and Fauna During Exploration Phase

Intentional or inadvertent destruction of plant communities during the exploration phase should be kept to a minimum. Major exploration works should require some form of environmental assessment to determine the importance of the vegetation assemblages in the areas to be surveyed, both in terms of their genetic diversity and current use. The statement of impacts should detail the exploration methods to be used and the scale of habitat destruction that their use would entail. Mitigation measures to be adopted should be clearly set out for the information of the licensing authority.

Impact: Beach Erosion

An isolated beach system which receives negligible amounts of sediment from surrounding beaches and near-shore areas is likely to experience erosion and shoreline recession if the rate at which sediment is mined exceeds the rate at which rivers or cliffs deliver new sediment. If, however, long-shore drift of sediment from beaches up-drift and near-shore areas is the principal source and sink of sand or gravel, mining the beach or frontal dune at a rate which exceeds supply will lead not only to beach erosion, but also to sediment starvation and erosion of down-drift beaches. The effects of mining may aggravate existing erosion problems such as those produced by over-grazing, burning of vegetation, or interception of the sediment supply to beaches by man-made river channel and coastal structures such as dams, harbour walls and jetties.

Beach erosion steepens the beach profile and may expose a rocky substratum. Beach-nesting species, such as turtles, may be lost from the area, and infrastructure and homes situated near the eroded beach may be subject to a greater risk of flooding. The downgrading of the beach as a recreational resource may also discourage tourists.

In addition to their wildlife and recreational functions, the frontal dune and beach constitute a flexible buffer against coastal erosion. In the interests of coastal protection, their integrity should not be destroyed. Mining of beaches and/or frontal dune ridges should be discouraged, and instead, extraction should take place landward of the frontal dune so that sand continues to be available for natural beach replenishment.

Impact: Initiation of Sand Movement

Disruption of the vegetation covering and dune shape may trigger blow-outs and/or major sand movements. Mobile sand may bury landward vegetation communities, such as pastures and forests, block routeways and entomb buildings. Infrastructure can be replaced, albeit at considerable expense, however, once unique vegetation communities are buried and lakes infilled, their store of genetic diversity is lost forever. Blowing sand also constitutes a nuisance for nearby inhabitants and may generate public resentment and hostility towards the project.

Large tracts of bare sand should not be exposed to wind and water erosion, as this may endanger surrounding land uses. A code of practice should ensure that the total area of bare sand exposed by sand mining operations at any one time is kept to a minimum. Man-made or vegetative buffers can help contain the area affected by sand blown, and may be erected specifically to help shield valued vegetation communities from blowing sand or damage from heavy machinery.

Rehabilitation should be an on-going process initiated immediately mining ceases in part of the site. The responsiblity for oversight and regulation of rehabilitation operations should not rest with the mining authority, as the necessary expertise may not be available.

Prior to licensing, consideration should be given to the likely success of a rehabilitation programme. Sand mining may destroy soil horizons and alter the level of the water table, making re-establishment of a similar vegetation community impossible. In harsh environments, long term stability of the worked area may be very difficult to achieve.

Worked out areas may be restored to something resembling their original use, for example wilderness or grazing, or an attempt may be made to up-grade or alter the land use. Sand and gravel pits close to populated areas may be converted to a diverse range of uses, for example, landscaped gardens, water parks, fish ponds, golf courses, land fill sites tor domestic refuse, or sites for sewage treatment ponds. The anticipated end-use should be known prior to commencing operations, as it may place constraints on the angle of slope or the amount and depth of materials mined, etc. The habitat and aesthetic quality of water parks and water bird sanctuaries can be enhanced if well-placed mounds of gravel or sand are left eventually to form islands and shallow water reed beds. The award-winning wildlife park, wild fowl refuge and salmon farm complex at Peacock Springs in New Zealand is one example of how well planned gravel workings can be rehabilitated for a number of profitable uses.

Restoration of wilderness may be a more complex undertaking, as the original topography and plant communities are often diverse and difficult to reconstruct. It is not always possible to restore the original topography due to the technical constraints of using earth-moving equipment on steep slopes. Typically, post-restoration topography is subdued and characterized by less complex, man-made forms. As the range of vegetation communities present is in part determined by topographical diversity, the flora and associated fauna may be correspondingly simplified.

When restoring mining sites in wilderness areas, care should be taken to re-mould the landscape into a range of naturally occurring forms. The original soil should be removed, complete with seed bank and root stock, prior to extraction, and spread onto the re-contoured area at the close of operations in that area. Additional planting should utilize locally occurring dune species. To ensure that sufficient transplants are available when and where needed, on-site nurseries may be set up to supply the project with suitable plants bred from on-site stock. It may, furthermore, be necessary to consider the re-introduction of game animals which may have migrated from the area during the disturbance. Shooting and trapping should be prohibited until faunal populations are re-established.

The application of fertilizer to new plantings should be controlled, as the proportion of spray fertilizer not taken up by plant roots will percolate rapidly through the sand layers to the ground water. This injection of nutrients could lead to eutrophication, and consequent severe impacts on lake and river flora and fauna. Fertilizer application should be kept to a minimum and slow-release forms used. The desirability of retaining dune-associated lakes and rivers in their natural state should be carefully considered.

Impact: Environmental Effects of Project-Related Infrastructure Development

Power supplies, roads and ports are major interventions in the environment. Their impact may be particularly severe in environmentally sensitive areas, e.g. drylands, or areas with extreme climates. The environmental impacts of these mining-associated developments should be addressed by separate environmental assessments and analysed within the context of overall regional resource development.

Impact: Opening Up of Wilderness Areas to Development

Remote areas often contain large timber stands and a rich diversity of wildlife. Infrastructure, such as roads, power supplies and port facilities, associated with large sand mining activities in remote areas may facilitate the opening up of previously inaccessible areas to logging and other extractive industries. Improved accessibility may also provide conditions conducive to the establishment of potentially less destructive uses, such as high quality, low density tourism. The potential costs and benefits of opening up a pristine area to a range of new developments should receive the attention of the relevant authorities prior to licensing.

Impact: Destruction of Historical Sites

Sandy coastal areas may contain evidence of human occupation valuable to historians and anthropologists. Mining completely obliterates historical sites. A comprehensive survey for sites of historical and anthropological interest should form part of the environmental assessment, or social impact assessment. The local, regional and national significance of sites pin-pointed by the survey should be assessed and all significant sites should be comprehensively documented before they are destroyed. Important historical sites may warrant preservation in situ, and hence may affect the location, scale, and economic return of the project. Claims to the land by indigenous tribes should be given full consideration, and their participation in decision-making actively sought.

Impact: Introduction of Exotic Species

If sand is destined for foreign markets there is potential for native species to be exported to or imported in bilge waters or attached to the outside of vessels. Exotic introductions have sometimes ravaged native fauna through predation, parasitism, or competition for food and living space. All possible pathways should be identified and the degree of risk assessed. Measures such as prohibition of the discharge of bilge waters in the coastal zone may reduce the likelihood of a successful introduction occurring.

River Bed Sources of Sand and Gravel

Towns, cities and major routeways have often been sited close to rivers to benefit from their many locational advantages. The bars and low water beds of rivers have, therefore, been exploited as convenient sources of sand and gravel for construction. The effects of river bed mining, although unspectacular, have been a major cause of the decline in the ecological integrity and usefulness of many rivers. Exhaustion of many river bed sources of sand and gravel and the growing recognition of the deleterious ecological consequences of river bed mining has led to the development of sea bed sources. However, river beds remain a major source of sand and gravel, especially for countries lacking coastline. The following impacts may occur.

Impact: Suspension of Sediment

The mechanical disturbance created by the dredging process stirs up clouds of fine silt. Waste water entering the river from gravel washing plants may also contain heavy concentrations of fine particles. Sediments from these sources reduce light penetration, and eventually settle, blanketing the river bed. These impacts impair the respiration and photosynthesis of submerged aquatic plants, and may result in reduced growth rates or death. The reduction in the extent of these vital habitats deprives river fauna of refuge from predators, and eliminates feeding and breeding areas. Fine settled particles make unsuitable spawning grounds for many river fish, and thus sedimentation may temporarily affect fish breeding. Organisms, such as molluscs, that must be anchored on smooth pebbles and rocks, decline and more tolerant, opportunistic species take their place. "Coarse" fish replace more desirable species which have a lower tolerance to disturbed conditions. Finfish and mollusc culture operations are also sensitive to elevated levels of suspended sediment. In high concentrations, suspended sediments block the gills of fish and the filter mechanisms of molluscs. The resulting stress, together with mechanical damage to sensitive tissues, may lead to disease outbreaks and mortality in farmed stock.

Some degree of re-suspension of fine particles by the dredger cannot be avoided. However, excessive levels can be avoided by utilizing extraction equipment which minimizes the production of fine sediments. High levels of fine material in the effluent returned to the river from sand and gravel washing facilities can be controlled by retention of the effluents in settling ponds prior to discharge. Government standards often stipulate the sediment content of effluents discharged from gravel washing facilities. These standards should be rigorously applied and updated if monitoring operations show them to be too lenient. Rivers that support diverse assemblages of aquatic species, including endemic or endangered plants and animals, should be used only by more sympathetic activities. Restoration techniques are not yet well developed, however, re-planting of submerged and emergent aquatic plants may be feasible.

Impact: Saline Intrusion

If mining takes place in the lower reaches of a river, the enlarged cross-sectional area of the channel in the vicinity of the dredge hole and the resulting lower water velocities may permit the tidal salt water wedge to penetrate further upstream. An influx of saline water may replace fresh water at water supply intakes, with disastrous effects for irrigated crops and domestic water supplies. Licence applications must be analysed carefully to ensure that sand and gravel extraction in estuarine areas will not alter the salinity balance and hence impose economic costs on other existing or future users.

Impact: Reduction in the Natural Capacity to Take Up Sewage Nutrients

Vegetated, shallow water areas in fast-flowing rivers have a substantial capacity to assimilate the nutrients in domestic and industrial wastewater. Municipal treatment works take advantage of this environmental service when they discharge partly treated wastewater into nearby rivers. Sand and gravel mining leads to the removal of large areas of shallows. The reduction in the extent of these productive areas and the lower water velocities in the dredge hole dramatically reduce the efficiency of nutrient removal. Increased nutrient availability stimulates algal blooms and the growth of surface weed mats. Dense plant growth reduces the appeal of the water body and shades out life beneath. Algal blooms may taint and colour the water and release toxic substances which are potentially hazardous to livestock and public health. Alternative potable water supplies may need to be found. These changes in water quality are detrimental to fish life and highly unpopular with anglers. The decline in aesthetic quality of the riverscape may, furthermore, depress tourism revenues.

Where possible, dredging should be restricted to the deeper areas of river channels, and hence avoid damaging shallow aquatic habitats.

It is clearely vital to balance the numerous competing and sometimes mutually exclusive claims on water resources. A regional planning approach should be adopted to enable the apportioning of available resources among planned and future uses in addition to those already present.

Impact: Erosion of the River Bed and Banks

The extraction of material from the river bed deepens the channel and enlarges the cross sectional area of the river. This results in a lowering of the water level and more sluggish flow conditions. If the quantity of material extracted exceeds the natural supply of sediment, a large extraction hole may persist. Erosion may then occur upstream and downstream of the pit for a distance of up to several kilometers to smooth out the river profile. This localized intensification or erosion may destablize the river banks, possibly leading to the collapse of dykes and bridges.

If the extraction rate is matched closely to the rate of supply, severe erosion can be prevented. Surveys and research are needed to enable estimation of the sediment budget so that a safe extraction rate can be calculated.

Impact: Clogging of the Bed of the Borrow Pit

The slower rate of water flow in the borrow pit leads to the deposition of fine sediment and organic matter held in suspension by the river. The sediments may clog the bed of the borrow pit, so preventing filtration of river water into the aquifer. The cumulative impact of a number of aggregate extraction operations may significantly reduce groundwater replenishment. A slight lowering of the local water table may be critical in marginal dryland areas, where it can result in crop failure or the loss of grazing pastures.

Organic matter may decompose in the sluggish waters of the borrow pit. The accompanying decline in water quality may have an adverse effect on fish and other aquatic life and on potable water supplies. It may be necessary to ban large scale gravel extraction in zones where other activities must not be put in jeopardy.

Impact: Noise

The increased human activity and mechanical noise at the extraction site may discourage migratory birds. Usually, waterbirds will move on to another suitable area. However, this may not be possible if the river is a "wetland of last resort" for some migratory species. Research may be needed to determine the importance of a given river channel as a migratory stop-over.

Impact: Visual Intrusion and Increased Road Traffic

Extraction machinery and piles of sand reduce the aesthetic quality of the riverscape. Consideration should be given to the desirability of planting natural barriers to screen the extraction area.

Road haulage of sand and gravel involves higher noise and vibration levels and an increased risk of road accidents. The capacity of the existing road network to support the additional traffic load should be investigated. Trucks should be routed to avoid disturbance to residential areas and other sensitive land uses.

Impact: Reactivation of Dry River Channels

Sand and gravel can be extracted from dry river beds with relatively few environmental impacts. However, there is a risk that the channel may be re-activated during or subsequent to mining by storm water run-off. If this occurs, in-channel structures such as bridges may be undermined. The hydro-geological setting of the site needs to be surveyed prior to licensing to investigate the potential hazard to in-channel structures.

Sea-Bed Sources of Sand and Gravel

Offshore areas contain large volumes of sand and gravel in close proximity to important urban markets. In some countries bordered by a coastline, depletion or land-based sources of sand and gravel has led operators to explore the aggregate resources of the sea-bed. Exploitatiion of near-shore marine sand and gravel reserves has often led to a range of environmental impacts which, although unseen, generate far-reaching effects. It is anticipated that the future extension of sea-bed mining into deeper waters may ease the impact on the coastal environment and make it possible to mine sand and gravel with acceptable environmental consequences.

The environmental impacts of marine mining are highly site-specific, and dependent on the dredging technology used and the physical and biological characteristics of the site. Consequently, most of the negative environmental impacts can be ameliorated by careful selection of mining sites and equipment. This section discusses the environmental impacts of sand and gravel mining in the shallower near-shore coastal areas.

Impact: Physical Disruption of Sensitive Vital Ecosystems during Initial Exploration

Prospectors are often obliged to explore environmentally sensitive areas, such as coral reefs, sea grass meadows and shellfish beds, in order to obtain a comprehensive understanding of the geology and morphology of the sea-bed. Non-physical exploration techniques, such as submarine photography, imaging with side-scan sonar, and acoustic methods should be used in preference to physical sampling, so as to minimize disturbance of these economically important ecosystems.

Where no centrally compiled survey of the resources of the continental shelf exists, repeated sampling of large areas may be necessary to locate suitable deposits. Repeated physical sampling on a project-by-project basis may interfere with the functioning of important marine habitats. Resource management agencies should take the lead in improving offshore resources management by compiling geological maps of continental shelf deposits. Initially, priority should be given to mapping the most critical areas, as these are most vulnerable to damage from repeated privately-conducted surveys.

Impact: Suspension of Sediment

Sea grass, coral reefs and shellfish beds in the vicinity of the extraction site may be damaged or killed by the sediment plumes created by physical disturbance of the sea-bed and overflow of fine sediments from the dredging vessel. Smothering by fine particles may impair respiration of plants and sedentary organisms, and clog the filter feeding mechanisms of shellfish. Soft corals which sway with the water currents can rid themselves of sediment, and hence improve their chances of survival. Hard corals are more susceptible. Loss of aquatic plants and destruction of reefs in turn means loss of habitats for organisms which are able to escape the unfavourable conditions. Recolonization of the mined area may, therefore, occur very slowly. The damage caused to fish breeding, feeding and nursery grounds can permanently affect the livelihoods of artisanal fishermen, and may add to the pressures on commercial fishery resources.

These impacts can be mitigated by informed site selection and high standards of management. Ecological surveys of coastal marine habitats should be undertaken, or existing surveys consulted to determine whether proposed extraction sites are close to known important marine habitats. Measures should be taken to prohibit mining of these areas.

Dredging equipment used should minimize the production of sediment plumes. In addition, the strength and direction of currents and tidal flows should be established so that the dredger can be positioned to avoid polluting important marine habitats with sediment.

Impact: Coastal Erosion

Coastal erosion is one of the major negative impacts of offshore sand and gravel extraction. It may occur in the following ways:

Firstly, coastal erosion may occur if large amounts of sand and gravel are removed from within the active coastal system. To restore equilibrium, waves scour material from beaches or soft cliffs. As beaches and cliffs diminish and recede, property is exposed to higher risks of flooding.

Secondly, the increased water depth above the dredge hole may alter wave energy and wave energy distribution. Beaches and soft cliffs erode if more powerful waves are able to reach the shore, or if wave energy becomes concentrated on a vulnerable section of coastline.

Thirdly, offshore bars serve a coastal protection function by forcing waves to break, and thus lose some of their energy, before they reach the shore. Dredging these sandy areas may, therefore, enable more destructive waves inshore.

Mining-related coastal recession can be avoided if the dredge sites are located outside the active beach system. Several countries have instituted standards governing the depth and distance from shore of areas exploited for the winning of sand and gravel. These standards effectively prevent the removal of sediment from the active beach system. Offshore bars and nearshore shallow sandy areas are, therefore, retained so that they can carry out their coastal protection function. In the Netherlands, for example, the offshore aggregate industry is only licensed to operate seaward of the 20 metre isobath to safeguard coastal defences.

Impact: Alteration of Material on the Sea-Bed

The physical characteristics of the material on the sea floor affects its value as a habitat for marine species. If mining is continued down to the underlying substrata, chalk, silt, mud, or other materials may be exposed. The newly exposed material may be a less desirable habitat for marine life. Mining operations should leave an adequate depth of the original substrata.

Impact: Deterioration of Water Quality in the Dredge Hole

If water movement is slack, fine sediments and organic matter may accumulate in the dredge hole. The high oxygen consumption of the decomposing organic matter may reduce the quality of the water in the hole and lead to anaerobic conditions. If these conditions persist, normal flora and fauna associations will not recolonize the worked out site. To avoid deterioration of water quality in the dredge hole, the following guidelines should be followed:

- the vicinity of the dredge site should be free from sources of organic matter, e.g. kelp beds;
- the mining site should be located in an area of shifting sands and ample flushing so that the pit is quickly filled at the close of mining operations; and,
- a large area should be dredged to a shallow depth in preference to the converse to ensure that water quality in the hole remains acceptable.

Impact: Physical Destruction of Organisms and Habitats

Gravel banks are important spawning grounds for many commercial fish species. Removal of material from these areas can, therefore, affect the yields of commercial capture fisheries. Hence gravel extraction and other potentially damaging activities should be excluded from gravel banks known to be favoured spawning grounds.

Dredgers are not selective and remove not only sediment, but slow-moving or attached plant and animal life. Clams, oysters and hibernating sea turtles may be caught up in the dredge and destroyed. Dredging should not be carried out over oyster beds and other productive areas, and should be restricted to periods of the year with least biological activity.

The sedimentation associated with sand and gravel mining projects has sometimes damaged fish farm stock. A minimum distance between fish farms and sand and gravel mining operations should be maintained.

Dragging anchors can collapse coral reefs. Therefore, dredger anchor points should be located only in extensive sand and gravel areas.

Impact: Conflict With Fishing Activities.

Bottom fishing and marine aggregate extraction are mutually exclusive activities. However, trawling can be continued in dredging areas at the risk of damaging fishing equipment. Where legislation does not bar fishing in licensed dredging areas, consultation mechanisms should be available to enable representatives of the two industries to come together to air their problems and foster a better understanding of each other's needs.

Information and Monitoring Needs

Baseline data should be established through systematic monitoring of the project area prior to commencement of mining operations. Ideally, the data collected should cover all seasons of the year so as to capture seasonal changes in biological productivity, weather conditions, tides, currents and species composition and abundance, etc. The baseline data enables comparisons of the conditions existing during operations and after the close of operations with pre-existing environmental conditions. It also provides a bench-mark against which to assess the success of the restoration works. A monitoring programme should be initiated prior to commencement of operations, and should continue throughout the life of the project. The data collected should be distilled and findings fed back into improved management of the project and associated restoration works. Monitoring operations may highlight deficiencies in environmental quality standards and regulations and can provide useful information for their adjustment. Potential environmental hazards may be predicted and measures taken to avoid them. Monitoring may include the following:

- changes in vegetation cover and composition;
- interference with important biological resources at or near the project site, e.g. coral reef, mangrove forests, rain forest, shellfish beds, and eel grass meadows;
- changes in the hydrological regime, including fluctuations in lake levels and river flows and the level of the water table;
- changes in faunal diversity and abundance;
- changes in water quality, including nutrient status, salinity, turbidity and sedimentation patterns;

- alteration of landforms present, e.g. river bed or sea-bed profile, morphology of sand dunes and beach;
- degree of stability of river banks, sand dunes or ocean bed; and,
- interference with significant archaeological sites.

The following information should also be collected in the early stages of the project cycle:

- nature and location of other users of the environment in the vicinity of the project area;
- standards, regulations and codes of practice for sand and gravel extraction projects;
- the locations of wetlands sites of local, regional and national importance, and other protected areas;
- approved channels and procedures for consultation with affected parties.

Conclusion

Sand and gravel extraction projects individually and cumulatively interfere with the ecological systems in which they are sited. Poorly planned, unregulated extraction of sand and gravel has contributed to the degradation of river and coastal areas, with economic penalties where existing and future options have been foreclosed. If sufficient attention is given to the capacity of the environment to support and withstand the various demands placed upon it, sand and gravel extraction projects may be located in areas which can sustain additional exploitation without jeopardizing other uses. Careful selection of mining equipment, enlightened management, and proper attention to reclamation works can further ensure that the environmental scars left by sand and gravel extraction projects are acceptable.

Further Information

For further information and advice on the environmental impacts of sand and gravel extraction, contact the global information service on the environment, INFOTERRA:

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