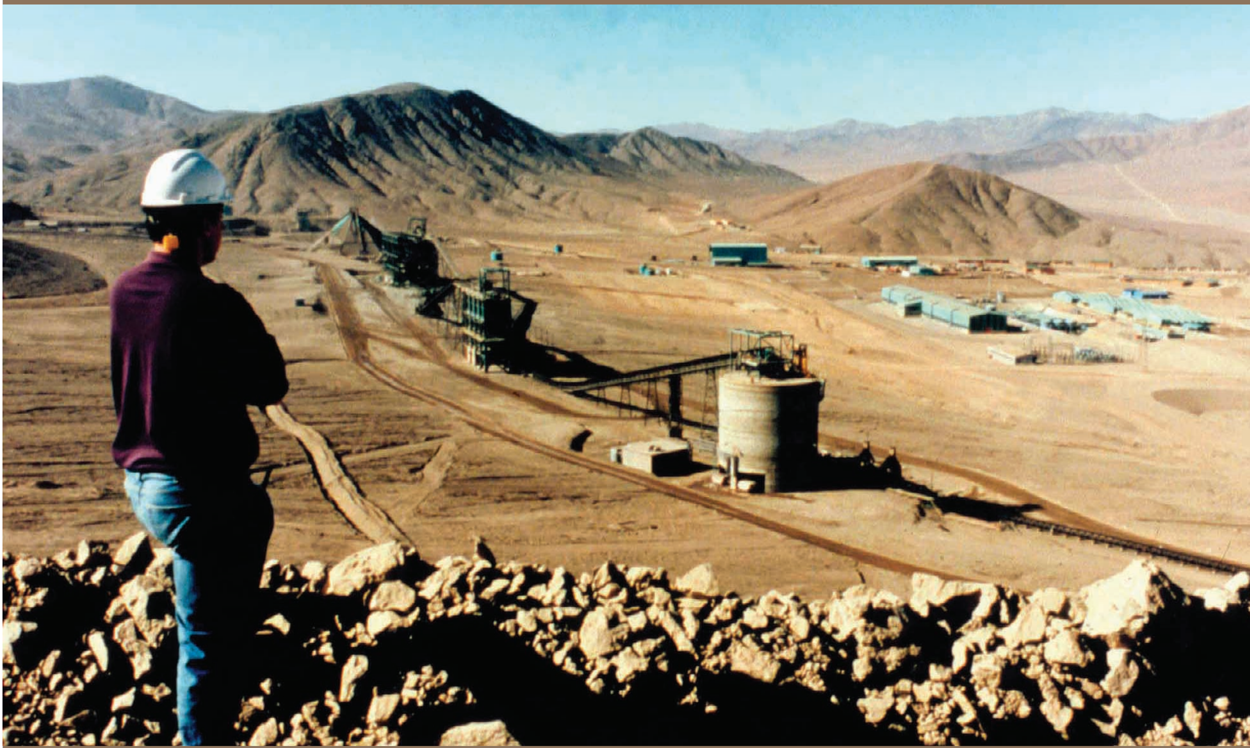
Extractive Industries in Arid and Semi-Arid Zones

Environmental Planning and Management

Joachim Gratzfeld, Editor



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IUCN – The World Conservation Union

2003

In collaboration with IUCN's Regional Office for West Africa (BRAO) and the Secretariat of the United Nations Convention to Combat Desertification (UNCCD)

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Executive summary

This publication aims to contribute to planning and management approaches that minimise land degradation and desertification in arid and semi-arid zones as a result of extractive industries operations. It is primarily intended to help those government departments responsible for the licensing, planning and monitoring of extractive industries activities to take account of environment and development issues in their decision-making. In addition, the document offers environmental planning and management fundamentals for extractive industries, local non-governmental organisations, and academic institutions.

Chapters 1-4 outline operational guidance on extractive industries development activities. This covers a range of topics, including an overview of the key characteristics of arid and semi-arid environments, and an introduction of the main stages of extractive industries development interventions (exploration, appraisal, construction and production, decommissioning and rehabilitation and ecosystem restoration). It discusses the principal environmental and social impacts of extractive industries development activities in arid and semi-arid zones, with recommendations and measures for environmental protection and sustainable management. The principal institutional arrangements and roles and responsibilities of government agencies, the private sector, civil society, international organisations and international conventions and national policy and legal frameworks are highlighted. This includes the main features of environmental management and planning, such as strategic environmental assessment, environmental impact assessment, environmental management plans, and monitoring and reporting.

Chapter 5 provides policy guidance. It summarizes the key guiding principles that will help government officials, environmental NGOs, and executives of extractive industries to consider ecosystem conservation needs of exploration and exploitation activities in arid and semi-arid lands to promote long-term sustainable development. This information is organised in three sections: Planning and Management of Natural Resources; Policies, Laws, and Institutions; and Monitoring.

Foreword

This publication is one of the first initiatives jointly undertaken by the Secretariat of the United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) and IUCN – The World Conservation Union. Its aim is to provide environmental planning and management guidance on extractive industries development activities in arid and semi-arid zones. These environments include ecosystems with unique ecological and biological features that contribute to global biodiversity; they also have significant potential for mining, gas and oil extraction, which is subject to concentrated exploration and exploitation efforts.

Developing this document was felt to be necessary, as potential trade-offs between biodiversity conservation efforts and extractive industries development activities in arid and semi-arid regions are likely to become more acute in the near future. Most of the countries with arid and semi-arid areas have poor economies, are affected by drought and desertification, and are striving for economic development, including initiatives such as mining and petroleum development. IUCN and the UNCCD Secretariat work together to minimise the impact of exploration and exploitation activities in arid and semi-arid zones on the environment, and to ensure that essential ecosystem goods and services are conserved to sustain long-term development.

A number of initiatives and studies related to extractive industries development activities and environmental conservation have been undertaken in the past, are ongoing or are planned (including the Global Mining Initiative, the Mining and Sustainable Development Process, and the Joint Dialogue on Mining and Biodiversity between the International Council on Mining and Metals and IUCN). Similarly, tools and guidelines have been developed by governments and various organisations that seek to integrate biodiversity conservation into petroleum and gas development. These include the Energy and Biodiversity Initiative; the International Petroleum Industry Environmental Conservation Association; the International Association of Oil and Gas Producers; and the Berlin II Environmental Guidelines for Mining and Sustainable Development. This publication is an effort to complement these initiatives with special regard to environmental planning and management issues in arid and semi-arid ecosystems.

Although this document primarily addresses governmental licensing, planning and monitoring agencies in developing countries, it may also offer a framework for companies, NGOs, universities and training centres. While the publication is a comprehensive source of information, environmental planning and management requires site-specific actions and measures that take into consideration the ecological and socio-cultural contexts of individual arid and semi-arid ecosystems.

The Secretariat of the UNCCD and IUCN are confident that this work contributes to a shared vision of the extractive industries development sector and the conservation arena in arid environments. It is a step toward coordination, cooperation and partnership among concerned stakeholders from the private and public sectors and civil society at large.

Hama Arba Diallo
Executive Secretary
United Nations Convention
to Combat Desertification

Achim Steiner
Director General
IUCN – The World Conservation Union

Introduction

Arid and semi-arid areas cover 30 percent of the world's land surface. Half of this area is in economically productive use as pastoral or agricultural land. These regions are inhabited by almost two billion people, many of whom live in developing nations, and who are directly dependent on the land's natural resources. While the exploration and extraction of minerals, stones, metals and hydrocarbons offer the potential for much-needed economic and social development, these activities can have widespread environmental and social consequences. If they are not well managed, these effects may persist well after the exploration and extraction processes have ceased.

The basic principles of sustainable development require that natural, social and economic resources be maintained for future generations. Sustainable development implies the recognition of stakeholder roles in defining the resources to be conserved and the principle of equitable distribution of such resources and decision-making powers.

The task is therefore to ensure that existing and new extractive industries development activities provide a fair exchange for the resources extracted in terms of the economic and human resources developed at the local and national levels, and with minimum degradation of the environment. Mineral and petroleum resources may be used to generate sustainable wealth and development in arid and semi-arid lands in such a way that the communities enjoy long-term economic benefits, and the local environment continues to provide its goods and services after extractive industries operations end.

In recognising that social, economic and environmental interconnectivity is an underlying principle for undertaking extractive industries development activities in arid and semi-arid zones, companies progressively relate to and conform with integrated management of land, water and living resources that promotes conservation and sustainable use of natural resources in an equitable way. This is often referred to as the ecosystem approach (Box 1), as described by the Fifth Conference of the Parties to the Convention on Biological Diversity (Decision V/6).

Box 1. The ecosystem approach

The ecosystem approach – the primary framework for action under the Convention on Biological Diversity (CBD) – is based on the application of appropriate scientific methodologies. These focus on the essential structures, processes, functions and interactions that exist between organisms and their environment. It recognises that humans, with their cultural diversity, are an integral component of many ecosystems. This focus on structure, processes, functions and interactions is consistent with the definition of "ecosystem" as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Article 2, CBD).

The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functions. Management must be adaptive in order to be able to respond to uncertainties of ecosystem processes; it should encompass elements of "learning-by-doing" or research feedback. Measures may need to be taken even in situations where cause-and-effect relationships are not yet fully established scientifically.

The ecosystem approach does not preclude other management and conservation initiatives, such as biosphere reserves, protected areas, and single-species conservation programmes, or approaches carried out under existing national policy and legislative frameworks. Rather, it can integrate these approaches and methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it is affected by local, provincial, national, regional and even global conditions (Source: UNEP/CBD/COP/5/23/V/6).

The need for environmental planning and management guidance

Today, many governments and private sector companies have recognized that economic success is inextricably linked to environmental and social performance. Realising the potential conflicts between development and resource management, some governments have already adopted national policies, laws and regulations for sustainable use of resources in arid and semi-arid zones in addition to more general regulations relating to environmental impact assessment, monitoring and auditing of environmental performance. A few countries, such as Australia, have developed guidelines for mining in arid environments, while a number of international and national mining and oil companies have been at the forefront in developing technical solutions to address environmental issues arising from their activities.

Various initiatives undertaken by industry associations, such as the Global Mining Initiative and the Mining and Sustainable Development Process illustrate the contribution that the extractive industries can make to conservation and sustainable development. The Energy and Biodiversity Initiative (EBI), convened by the Center for Environmental Leadership in Business, is developing tools and guidelines for integrating biodiversity into oil and gas development. This initiative seeks to be a positive force for biodiversity conservation by bringing together major energy companies and leading conservation organizations, including IUCN, to share experiences and build on intellectual capital to create value and influence key audiences.

IUCN, in collaboration with a number of extractive industries-related organisations, such as the International Petroleum Industry Environmental Conservation Association (IPIECA) and the International Association of Oil and Gas Producers (OGP; formerly the Oil Industry International Exploration and Production Forum, or E&P Forum), has been producing various guides for environmental protection. These include guidelines for oil and gas exploitation in the tropics, and in mangrove and arctic and subarctic onshore environments.

In the lead-up to the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa in 2002, and subsequent to it, IUCN has been engaged in a substantive dialogue with the International Council on Mining and Metals (ICMM). Its purpose is to enhance the mining sector's contribution to biodiversity conservation through introducing, developing and implementing best practice.

Despite these developments there clearly remains a need for more work and research on the most suitable methods and techniques for addressing issues of sustainability and environmental protection of extractive industries development activities in arid and semi-arid zones. Policies and technical documents on extractive industries interventions need to be backed up by discussions and agreements between different companies, groups and governments in different countries.

Scope and purpose of this document

The scope of this document encompasses the non-polar arid and semi-arid ecosystems of the world's dry regions. It aims at providing fundamentals of environmental planning and management for mining and petroleum development activities in these zones. Its overall goal is to contribute to planning and management approaches that minimise land degradation and desertification as a result of extractive industries operations. The principal audience of this document are the government agencies and departments responsible for licensing, planning and monitoring of such developments. This document should help to create a common understanding of the issues, impacts, and stakeholders involved with establishing extractive industries in arid and semi-arid zones. In addition, the information provided in this publication may also serve as a work of reference for industry executives responsible for planning and undertaking extractive activities in arid and semi-arid zones, and for local environmental and development-oriented NGOs. This work should assist these different stakeholders to take account of environmental sustainability issues when taking decisions about mining and petroleum operations in arid and semi-arid zones.

Processes, roles and responsibilities of various stakeholders, including mining and petroleum companies, communities adjacent to mines and oil fields, and NGOs representing different conservation and development interests are highlighted in this document. It recognises that numerous technical guides are available on mining and the environment, and no attempt is made to replicate these. Rather, it attempts to complement existing work on environmental planning and management of extractive industries development activities by focusing on issues related to arid and semi-arid zones. In practice, these fundamentals need to be considered according to specific sites. In each case, the application of recommendations and measures will depend on the ecological context of extractive industries development interventions, the institutional and legal structures and the resources available.

Chapter One

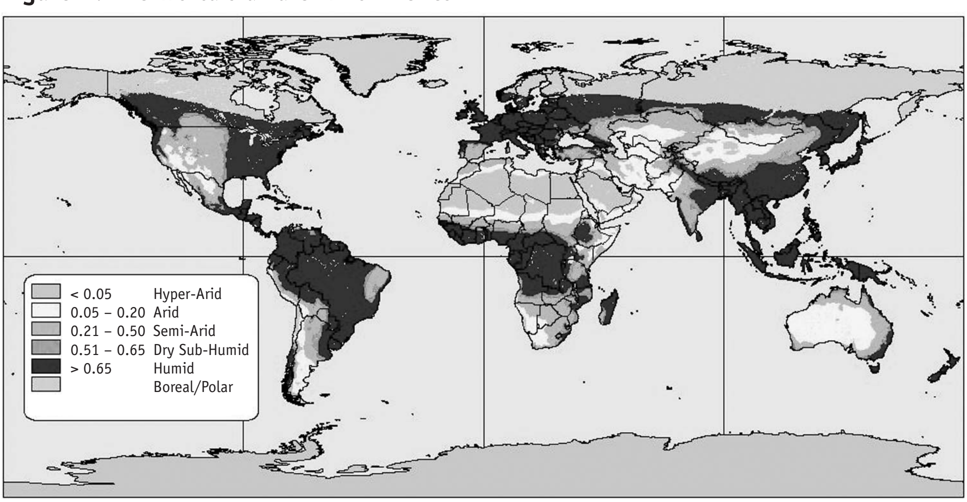
Characteristics of arid environments

1.1 Introduction

The United Nations Convention to Combat Desertification (UNCCD) defines Arid, Semi-Arid and Dry Sub-Humid zones as "areas, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration [the aridity index] falls within the range from 0.05 to 0.65." Hyper-Arid zones are characterised by a ratio typically less than 0.05. Together, these arid environments account for over 47 percent of the landmass of the earth and are spread geographically across all continents. The African continent contains the largest area of arid environments, while Australia has the highest proportion — about 75 percent of its area.

The physical and climatic characteristics of arid environments — and of their flora and fauna — vary considerably. Physiographic features, proximity to the coast and altitude contribute to the character of specific arid environments. Plants and animals have adapted to extreme environmental conditions; many are unique and endemic, and thus contribute to global biodiversity. Indeed, various present-day crops, such as wheat, maize, barely, and millet, as well as livestock species, originate from wild progenitors in arid environments. Many arid ecosystems are characterised by high natural resilience, but today they face unprecedented pressures as a result of human-induced changes.

Figure 1. The world's arid environments



Source: FAO/AGLL/GIS (SDRN), 2002

1.2 Physical environment

1.2.1 Climate

Most arid regions are located beneath areas of high pressure into which rain-bearing frontal systems can only rarely penetrate. Consequently these areas experience low, scattered rainfall patterns, which are highly variable both seasonally and annually. Rain falls infrequently in isolated storms, which may cause flooding in dry river systems. The variability of these events typically leads to periods of several years of drought or heavier-than-average rainfall. There is a wide daily and seasonal variation in temperature. Cloudless skies and dry air allow the ground and lower atmosphere to become intensely hot during the day. When this heat radiates to the atmosphere after sunset it results in sharp cooling at night and even frost in winter. Air masses are generally stable and wind speeds are often light. Localised surface heating, combined with the absence of trees and open landscapes, may produce high local winds and high-velocity vortices or dust devils.

1.2.2 Air quality

Air quality in arid and semi-arid zones varies from pure to having high levels of particulates. Large quantities of dust are produced by weathering of rocks, deflation of soils and abrasion from wind. Dust and sand may also be blown from sediments and dry cultivated areas. Once caught up in air currents, particles can be carried over great distances, causing dust storms or short-lived dust devils.

1.2.3 Landscapes

Arid environments encompass a broad range of dramatic landscapes, including mountains, table lands, hilly terrains, low-angle bedrock, alluvial fans, river plains, deltas, wadis and dry riverbeds, dunes and sand seas, sand sheets, desert pavements and flats, and recent volcanic deposits. These features are important both visually in a generally treeless landscape, and biologically as micro-habitats. The topography of arid environments redistributes water resources, allowing vegetation and trees to grow in the areas surrounding valleys and near sources of permanent ground water. In areas of slightly higher rainfall, grasslands and savannah landscape types may predominate.

Sperrgebiet, Namibia.
Photo, Anglo-American

1.2.4 Soils

Soils in arid and semi-arid zones can be shallow or deep, comprising sands or clays, and can vary in acidity and fertility. Productivity depends on the soil's water-holding capacity, which tends to increase with depth and organic content. Sandy soils have less water-holding capacity than clay soils.

The often sparse vegetation in arid and semi-arid zones allows soil particles to become dislodged by water and wash into the pore spaces in the soil, making the ground harder and less absorbent (soil scaling). This results in further runoff and erosion of fine particles, containing nutrients, from the surface. Once eroded, the soil is less able to support vegetation and more susceptible to further modification by water and wind.

Sahara Desert, Ténéré, Niger.
Photo, IUCN/Jim Thorsell

The geomorphology of many arid regions creates large inland drainage basins with no natural outlet. Evaporation of water leaves salts behind in the soil. Unless these salts are dissolved by rainfall and redistributed, salinisation of the land will result.

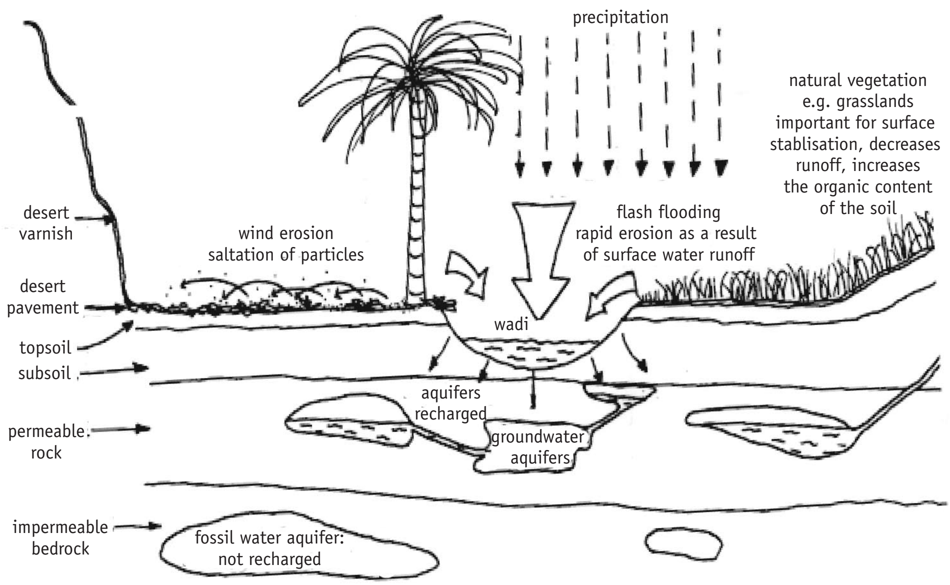
1.2.5 Water resources

A shortage of water characterises arid environments. Apart from short-lived surface waters that remain after rainstorms, most water resources are underground. This includes fossil water, or geologically trapped water; since it is no longer being supplemented by rainfall, it is a finite, non-renewable resource.

The quantity and nature of surface water is determined to a large extent by the low and variable rainfall, as well as topography, soil permeability, vegetation cover and rate of evaporation. In some areas small rivers or lakes may form following rainfall. Other water bodies may be fed by springs. Surface water may also occur in rivers or wadis, which originate in more humid regions or mountain catchments. Wetlands that form in arid environments are very important features, both as natural ecosystems and areas of high biodiversity, and as centres for human activity.

Ground water is distributed unevenly and often very deeply. Only a small proportion of ground water enters the hydrological cycle or is recharged locally; some aquifers are in closed systems and therefore do not refill when they are drained. Open systems are generally recharged from areas with higher levels of rainfall, through rivers, canals or ground water movement. Some deep aquifers comprise fossil waters, created many thousands of years ago under more humid climatic conditions; these may be of very good quality (Figure 2). The quality of the shallower ground water varies from fresh to saline according to the host rock; it may contain dissolved or suspended chemicals. Although ground water in arid environments may be unsuitable for human consumption or agricultural use, it can still be utilised for mining operations.

Figure 2. Natural processes in arid and semi-arid areas



Source: Scott Wilson Ltd.

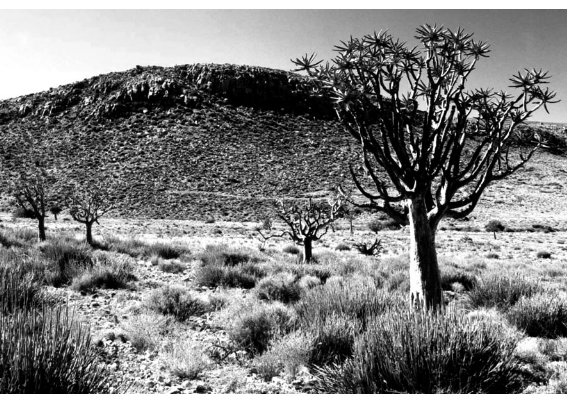
1.3 Biological environment

1.3.1 Vegetation and flora

Vegetation types display a high diversity. They vary considerably from region to region, and include different types of grassland, rangeland, woodland and forest that have adapted to survive under conditions of irregular rainfall, high solar radiation, fires and periodic drought. Vegetation depends on the local soil types, nutrient status and climatic conditions. Year-round cover is characteristically open and patchy. Biomass may vary considerably from year to year, but species composition generally remains constant.

Plants in arid environments have evolved to survive extreme climate conditions. They are either drought-enduring (such as cacti and succulents) or drought-avoiding (such as annual grasses). Halophytes have a remarkable tolerance to saline conditions. Three basic categories of plants grow in arid regions:

- Ephemeral plants are herbaceous (non-woody), with extremely short life cycles of approximately 6-8 weeks. They do not require drought resistant properties as they grow only during periods of moisture. Their seeds can remain dormant in the soil for long periods of time until sufficient rainfall and favourable temperatures activate their germination. These plants are small with shallow roots. They grow, flower and die very quickly, returning nutrients to the soil and paving the way for the colonisation of other plant types. Arid land topsoils contain high proportions of seeds, which are a valuable resource for rehabilitation of degraded lands.
- Succulent perennial plants are able to endure drought. They have a waterproof layer of waxy material on their outer surface to minimise water loss and an enlarged stem or leaves, which enables them to store an increased volume of water. These include the *Cactaceae* of the New World and succulent *Euphorbiaceae* of the Old World.
- Ligneous perennial plants range from grasses and woody herbs to shrubs and trees. They can be evergreen or deciduous and are very hardy. Many woody perennials are spiny or harsh-textured. Some produce seeds that only germinate if the seed coat is scraped or burned off.



Northern Cape, South Africa.
Photo, Anglo American

The flora of arid environments can be very rich in diversity as a result of adapting to the harsh and variable climate. Many plant species in arid areas are endemic and are restricted to specific habitats. Some species found in arid environments are relics of earlier, more humid or drier periods, surviving in particular locations or refugial sites (e.g. mountains in the Sahara Desert).

1.3.2 Fauna

The fauna in arid environments also has to cope with climatic extremes. Physiological and behavioural adaptations have been made to the variable amounts and spatial distribution of food, the generally unpredictable conditions and the extreme diurnal temperature variations. These include the following:

- nocturnal behaviour — many animals avoid the intense heat and risks of dehydration during the day and emerge at night to feed;
- burrowing — a much higher proportion of the fauna in arid environments live underground;

- water independence — some species can live for many months without access to drinking water, obtaining the necessary moisture for survival from dew and from eating plants with stored water, such as roots and melons; and
- mobility — some animals will migrate hundreds of kilometres to take advantage of vegetation growth in response to rainfall in different areas. As a result, animal populations can fluctuate considerably from year to year.

Arabian Oryx, Namibia.
Photo, IUCN/Jim Thorsell

Wetlands in arid and semi-arid zones are often very important habitats of animal biodiversity. They not only support aquatic fauna that have adapted to changing conditions (such as periodic drying up), but are also critical staging points for migrating birds. Without these wetlands, migration might be impossible.

1.4 Socio-cultural environment

1.4.1 Population and settlements

A considerable diversity of people of different ethnicities and user groups live in arid environments. They range from indigenous peoples, such as aboriginal hunter-gatherers and nomadic pastoralists, semi-nomadic transhumance practitioners, through subsistence farmers in small settlements, to modern industrial town-dwellers. In general, however, the scarcity of water and the difficulties of agriculture have meant that populations in arid environments tended to be sparse, with small groups of people concentrated around water sources. The water resource has usually determined the size of the settlement. Populations in arid and semi-arid zones, as in all other regions, are increasing, and the pattern of settlements is changing.

Arid regions are known for the richness of their cultural diversity. Because of the relative isolation of traditional communities living in arid environments, a strong sense of cultural identity has often developed. Many settlements and religious sites of previous cultures — including religious buildings, shrines and sacred sites — remain as historic and archaeological resources in arid and semi-arid regions. The dry conditions are favourable to their preservation. Not only is this archaeological record of great importance academically and culturally, it has increasing economic significance for the tourism sector.

1.4.2 Land use and tenure

Arid and northern semi-arid zones are characterised by patchy pastures and arable land. This being the case, traditional land tenure systems and usufruct rights are often complex, overlapping and situational. Table 1 summarises types of vegetation and land use in relation to aridity zones.

Table 1. Aridity zones, vegetation and land use in arid environments

Zone	Vegetation	Land use
Hyper-arid	Accidental	Very little
Arid	Bushes and woody shrubs, succulents, some perennial grasses and many annual grasses	Grazing
Semi-arid	Grassland, tropical shrub and some savannahs	Pastoral grazing, rain-fed agriculture
Dry sub-humid	Grasslands, woodlands and savannahs, maquis, chapparal, steppes	Grazing and ranching, intensive livestock production, rain-fed agriculture, irrigated agriculture, forestry

1.4.3 Livelihood strategies

The lifestyle and economic strategy of people living in arid and semi-arid zones is traditionally characterised by their need to ensure adequate water supplies and protection against food shortages. Nomadism, or moving with livestock between water and pasture resources, has been one of the main livelihood strategies. Food and medicines from the wild are often a very important addition to local diet and health care, and to the local economy. As resources become more secure or permanent, settlement in one place becomes possible, with land-use being principally pastoral and agricultural.

Chapter Two

Extractive industries development activities

This chapter describes the exploration, production and decommissioning phases of extractive industries. The mining and petroleum industries have similar operational phases, including the following:

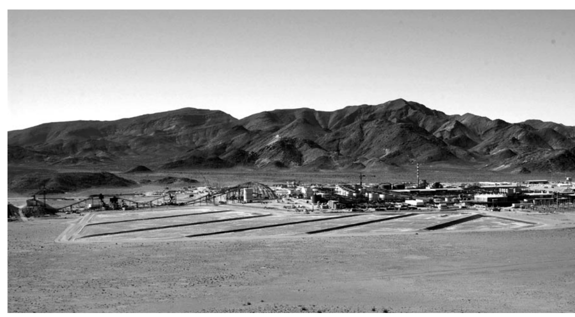
- exploration and survey (Phase I);
- appraisal/feasibility assessment (Phase II);
- construction, production, refining/processing, and distribution (Phase III); and
- decommissioning and site rehabilitation and ecosystem restoration (Phase IV).

An overview of activities is presented separately for both sectors. Activities carried out by both sectors, such as the setting up of base camps and production sites, decommissioning and rehabilitation and ecosystem restoration, are described jointly.

2.1 Materials extracted in arid and semi-arid zones

Various types of materials are extracted in arid and semi-arid zones, including the following:

- hydrocarbons, including oil and gas;
- metals and metallic minerals, including iron, tin, bauxite, aluminium, borates, titanium, cobalt, manganese, nickel, lead, zinc, chromium, uranium and vanadium;
- non-metallic and industrial minerals such as phosphates, asbestos, coal, oil shales, salt, talc and sulphur;
- precious minerals, for example, gold, silver, platinum, zircon and diamonds; and
- construction and industrial minerals, such as stone, clays, sands and gravel.



Zinc mine, Namibia.
Photo, Anglo American

2.2 Mineral exploration and extraction

Mining companies vary widely in the scope of their activities. They may specialise in one, or undertake several or all, of the above operations. They range from large multinational operations, active in many countries, to medium-sized companies, to small-scale and artisanal operations that are typically more informal. Table 2 provides a simplified summary of the phases of mining operations and the on-site requirements of each phase.

Table 2. Operational phases of mining activities

Phase	Activity	On-site requirements
I	**Desk study:** identifies areas with favourable geological conditions; literature searches, accessing local archives not publicly available	
	Aerial survey: identifies favourable landscape features	• low-flying aircraft over the study area
	Geochemical survey: collects samples of rocks, soils, water and sediments and vegetation for chemical analysis	• minimal equipment needs • light-vehicle access with extensive coverage of the area • water sampling
	Geophysical survey: measures overburden, delineates rock formations and geological structures	• line-cutting and access
	Exploration drilling/trenching: verifies the presence or absence of a mineral resource and quantifies the reserves	• earth-moving and drilling facilities • access for equipment • base camp facilities • water and power supply • storage facilities • waste disposal facilities
II	**Appraisal:** determines if the resource is economically feasible to develop; development of an environmental impact assessment and an environmental impact strategy	• earth-moving and drilling equipment • large base camp • water and power supply • drill and trench sites • access, storage and waste disposal facilities
III	**Construction and production:** infrastructure (access roads, electricity, water supply); construction of facilities and staff housing; extraction and processing of mineral ore etc. through open-cast or shaft mines; transport of ore and minerals away from the site	• installation of earth-moving and mining equipment • blasting facilities • ore-processing facilities • export facilities • semi-permanent staff accommodation/facilities • water and power supply • improved access, storage and waste-disposal facilities
IV	**Decommissioning, rehabilitation and ecosystem restoration**	• equipment to make mines and waste-disposal sites safe • equipment to remove installations • equipment to rehabilitate and restore site • equipment for ongoing treatment of mine drainage and seepage

Phase I: Exploration

Desk study

Initially, geological maps are reviewed to identify major rock formations and sedimentary basins. Aerial photography may be used to investigate landscape features that are indicative of basin formation, such as faults or anticlines.

Aerial surveys

Additional data may be collected using satellite remote sensing and aerial geophysical surveys. A range of geophysical surveys may be conducted over a wide area to identify geological features indicating underlying minerals. These may include measurements of electrical conductivity, magnetism, natural radioactivity or gravity anomalies often undertaken from a light aircraft or helicopter. Techniques such as infrared imagery can help classify surface rock and highlight vegetation changes, which could also indicate the presence of underlying minerals.

Geochemical surveys

These are conducted on the ground as part of mining exploration and involve gathering and analysis of water samples, stream sediment, soil, vegetation and rock outcrop samples for their mineral content. This initial stage of exploration has a limited impact, as equipment requirements are minimal and much of the work can be undertaken on foot or using light vehicles.

Ground geophysical surveys

These are conducted on the ground and are intended to map the geological structures and to measure the overburden. The impact may be greater than geochemical surveys, and will involve line-cutting of vegetation and vehicular access.

Exploration drilling

When exploratory surveys highlight a promising area for drilling, the next stage is to confirm the presence and extent of mineral resources by drilling one or more exploratory boreholes. Typically up to a dozen boreholes will be drilled over an area of several square km. Drilling may last from one to three months, with operations taking place 24 hours a day. Sample cores are taken for mineral analysis.

Exploration work, Namibia.
Photo, Anglo American/Phil Tanner

Three different drill rigs are used in sequence once a resource has been identified. Their "footprints" and impacts are far less than those used in oil exploration.

Rotary air blast drilling (RAB) is used as a quick appraisal method to gather geochemical information. Drill holes are typically 40 m deep and spaced up to 500 m over several km. The area of impact, or pad, may be as little as 5 by 5 m.

Reverse circulation drilling is based on the geochemical targets identified by RAB. This technique is more accurate and can drill deeper and into harder ground. Typical hole depths are 80 m, with drill pads of 20 by 20 m. It takes 5–40 hours to drill the hole.

A diamond drill rig is used to take core samples. It provides geotechnical information about the site and highly accurate geochemical analyses. This technique is used mostly during the feasibility stage, when the size of the resource is being determined. Drilling typically involves holes 100 to 150 m deep; the rig stays several weeks on each hole and drill pads are typically 30 by 30 m.

Generally, if the site is not considered commercially viable, the equipment (e.g. the drilling rig) is dismantled and moved for reuse at another site. The site should be left in a safe and rehabilitated condition and, where possible, restored to its original state (for further details on decommissioning, site rehabilitation and ecosystem restoration see Phase IV).

Phase II: Appraisal and feasibility studies

Prior to production, the company will carry out an appraisal to define the size and nature of the resource, determine how production will proceed and evaluate whether it is economically feasible. For sites with mineral potential, evaluation drilling and trenching are carried out to determine the nature of the mineralised zone. Since deposits are often complex, many samples are needed to establish their grade, size and continuity.

A preliminary feasibility study is prepared, based on a conceptual mining project, to evaluate whether it is economically and technically feasible to extract the deposit. In conjunction with this stage a preliminary environmental appraisal needs to be carried out to identify and assess the potential environmental and social issues associated with production activities and closure plans, and to determine the need for protective and mitigation measures. If the preliminary feasibility study results in the decision to proceed, a full feasibility study is prepared. A comprehensive environmental impact assessment (section 4.2.2) also needs to accompany the necessary consent applications.

Phase III: Construction, production, processing and distribution

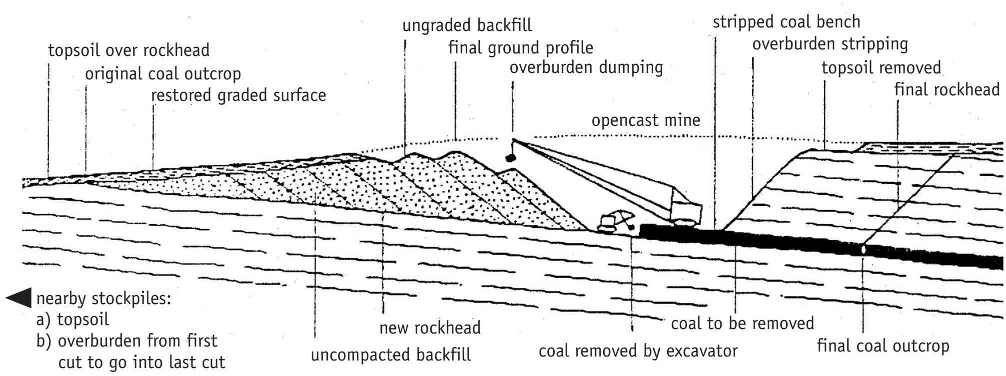
The circumstances and type of material will determine the method of extraction, either from the surface or underground.

Surface mining

There are two main types of surface mining (also known as open-cut or opencast). Strip mining is suitable for extracting materials such as low-grade coal or limestone, which lie close to the surface but may extend for many square km. Each strip is designed so that only a relatively small area is actively mined. This allows overburden to be removed on the advance side and replaced on the retreat side, where mining has already taken place.

Bench or open-pit mining is used for extracting rock from the earth's surface when minerals lie in massive deposits, which can be deep (up to 1000 m) and extend over several km (Figure 3).

Figure 3. Diagram of an opencast mine



Source: Waltham, T. 1994. *Foundations of Engineering Geology*. Routledge: London, p. 60

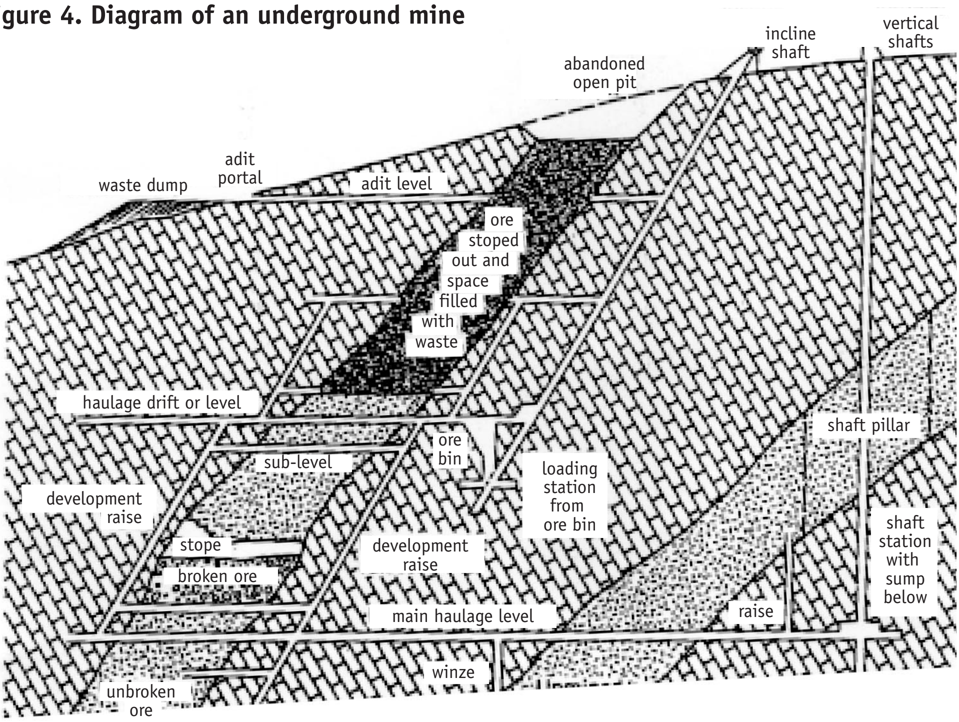
The first activity associated with extraction from surface mines is removal of overburden, including topsoil, to reveal the mineral deposits. Removal is done by bulldozers and scrapers or by blasting; the topsoil and overburden may be stored for later re-use. This is followed by removal of the ore and transfer by access roads, typically constructed on the edge of the pit, to the processing area. The pit is progressively dug deeper into the ground in successive levels, leaving "benches" that support the sides and allow access for earth- and rock-moving vehicles.

A third form of surface mining is placer mining on alluvial or eluvial deposits. Deposits of gold, tin, titanium and platinum are mined by ground sluicing, and by excavating with dredges and loaders. Processing is typically done by gravity separation, e.g. for gold, and by techniques such as mercury amalgamation at the site for final gold recovery. Placer operations vary in size from the artisanal, e.g. the classic gold rush hand-miner, to large-scale mining and processing.

Underground mining

Underground mining is used to exploit seams of minerals that lie below the surface (Figure 4). A number of techniques are used, such as pillar and stall, bord-and-pillar and room-and-pillar (predominantly used for coal but also employed for salt, limestone, etc.), stoping (usually used in metal mines to extract vein deposits), block caving, and top-hole longwall (including cut-and-fill) mining. All these techniques involve blasting or digging a shaft to follow a vein underground. Rock cutters and drilling machines are predominantly used in underground coal mining while metal mining may involve different extraction methods. Although different minerals are extracted and variations in techniques may be involved, the general methods of extraction are essentially the same, involving a combination of explosives for blasting and equipment to move earth and rock. Blasting requires considerable safety precautions, as well as attention to minimising disturbance to local communities, livestock and wildlife.

Figure 4. Diagram of an underground mine



Source: Evans, A.M. 1993. *Ore Geology and Industrial Minerals: An Introduction*. Third Ed. Blackwell: Oxford, p. 20.

A different form of underground mining involves dissolving the mineral in a liquid and pumping it out, similarly to oil extraction. There are two forms of this process:

- Solution mining is used for soluble salts, such as sulphates and potash. Water is injected into underground strata and dissolves the water-soluble minerals, which are then extracted as a liquid brine. This process leaves behind an underground cavity where the mineral has been removed, which can cause subsidence later.
- In-situ leaching is carried out by the injection of chemicals known as lixiviants. These can be acidic, basic or neutral, and often contain oxidants to extract minerals such as uranium and copper. Chemicals are contained within the ore zone by controlling the well-field's hydrologic gradients.

Mineral processing

Once the rock or ore has been removed, it will require some form of processing to produce the mineral or concentrate, which is then exported from the site. Processing may be very simple (as it is, for example, with coal, aggregates, sand and gravel) or might entail more complex methods, involving some or all of these activities:

- crushing, washing and sizing — physical processes to produce a clean raw material of roughly uniform size;
- separation processes — to separate out different materials, either according to specific gravity (e.g. gravity separation, flotation and hydrocyclones) or, in the case of ferrous materials, based on magnetic properties;
- chemical processes — to extract metal salts, etc. through leaching with acids, bases or oxidants; and
- heat and electric processes — to extract purified materials, e.g. refining and smelting.

Minerals may be processed on site, or the raw ore may be transported for processing elsewhere (i.e. where there is greater availability of water and energy). Sometimes partial processing is carried out to decrease the bulk of the materials and reduce transport costs.

Some of these activities require few if any chemical additives and produce relatively benign byproducts. Others, such as chemical leaching and flotation processes, involve the use of specific chemical reagents, which include toxic organic solvents. A summary of the key techniques used for processing of various materials and the associated products and process wastes is provided in Annex 1.

Extraction and processing activities require significant amounts of power and water, both of which may be difficult to obtain in isolated arid and semi-arid zones. If water is required for processing, then dewatering of the washings and tailings for reuse is essential. Contaminants in the water, which may be toxic, mean that considerable care needs to be taken in the design of tailings dams and the disposal of leachates. Other solid, liquid and gaseous wastes and emissions may be produced during processing. The key waste streams resulting from extraction and processing of minerals, and disposal and treatment options, are summarised in Table 3.

Table 3. Key waste streams

Waste streams	Treatment and disposal methods	Issues
Overburden and waste rock		
Rock and soil cleared away before or during mining operations	Topsoil to be stored for reuse during rehabilitation and restoration Overburden usually placed near the site and may initially be used to fill depressions and build up level areas around the mine or stored for backfilling of benches and pits Waste rock may be used to develop town sites, roads etc. to service the mine and the local community	Acid Mine Drainage (AMD) resulting from oxidation of sulphide minerals when exposed to air and water, producing acidic, sulphur-rich waters with elevated concentrations of iron, sulphate and other metals; this process is accelerated by certain bacteria Sediment production and loading of rivers resulting from increased erosion
Mine water		
Drainage/dewatering of mines to lower the water table	Neutralisation and aeration Removal of potentially toxic contaminants, e.g. arsenic, chromium, copper, cyanide, lead, selenium, nickel and zinc Passive treatment through constructed wetlands	Treatment of mine water may have to continue for many years after mine operations cease

Tailings		
Fine-grained mineral waste produced by milling operations during processing	Dewatering reduces the moisture content of the tailings for transport and disposal by truck Slurried tailings may be transported by pipeline from the mill to the disposal area Typical disposal is in surface impoundments or as backfill in underground mines Dry tailings storage with rock cover may be appropriate	Acid mine drainage (AMD) Toxic seepage Dust generation Erosion
Process effluent		
	Effluent discharged to receiving waters from tailings impoundments, sedimentation basins and stormwater drainage Neutralisation and aeration Treatment in constructed wetland	May contain hazardous chemicals Ponds may leach into ground water or overflow during rainstorms
Air emissions		
particulates, methane, SO_x and NO_x	Appropriate siting of mining, milling and screening operations downwind of communities and staff accommodation Hazardous emissions from particular processes may need specific treatment to comply with emission standards	Dust may contain toxic contaminants from extracted minerals, but usually in low concentrations Methane generation from coal mines contributes to greenhouse effect and global warming

Phase IV: Decommissioning, rehabilitation and ecosystem restoration

In areas where extractive industries operate evidence of old and abandoned sites can often be seen. There is an increasing awareness, however, that safe decommissioning, site rehabilitation and ecosystem restoration are part of the obligations of an extractive industries company. This requirement is usually built into the terms of the concession, and companies may have to put part of their production income into a rehabilitation/restoration or sinking fund. The level of rehabilitation and future use will have to be agreed to by authorities and local communities, in principle before the start of operations, and in detail when operations end. In some cases the site can be restored to its original state, but this may not always be possible. Site restoration may involve replacement of soils where contamination has occurred, along with measures to encourage revegetation (see also section 4.2.3).

A major concern will be the persistence of acid mine drainage and leachates from tailings ponds. Pumping and treatment of such liquids may have to continue for many years to prevent contamination of surface water and ground water.

Rehabilitation of zinc mine, Namibia.
Photo, Anglo American

2.3 Petroleum exploration and extraction

Oil companies vary widely in the scope of their activities. They may specialise in or undertake several or all of the development phases. They range from large multinational operations, active in many countries, to medium-sized companies that work in more limited regions. Specialised companies often provide services, e.g. survey and drilling, on a contract basis. Table 4 provides a summary of petroleum exploration and extraction phases and on-site requirements.

Table 4. Operational phases of petroleum exploration and production

Phase	Activity	On-site requirements
I	**Desk study:** identifies area with favourable geological conditions; literature searches, accessing local archives not publicly available	
	Aerial survey: identifies favourable landscape features	• low-flying aircraft over the study area
	Seismic survey: provides detailed information on geology	• road or helicopter access for personnel and equipment • vehicle access and tracks • base camp facilities
	Exploration drilling and trenching: verifies the presence or absence of a hydrocarbon reservoir and quantifies the reserves	• drill stem testing facilities • access for equipment • base camp facilities • water and power supply • storage facilities • waste disposal facilities

II	**Appraisal:** determines if the resource is economically feasible to develop; environmental impact assessment and environmental impact strategy	• additional drill sites • large base camp • water and power supply • additional access, storage and waste disposal facilities • oil storage facilities
III	**Construction and production:** infrastructure (access roads, electricity, water supply); construction of facilities and accomodations; production of oil and gas from the reservoir through formation pressure, artificial lift and possibly advanced recovery techniques until economically feasible reserves are depleted Processing and refining Transport and pipelines	• increased oil production (well heads, flow-lines, gathering stations) • separation and treatment facilities • more oil storage tanks • gas production plant, flares • export facilities (pipelines, tankers) • semi-permanent staff accommodation and facilities • water and power supply • improved access, storage and waste disposal facilities
IV	**Decommissioning, site rehabilitation and ecosystem restoration**	• equipment to plug wells • equipment to remove installations • equipment to restore site, landscape and revegetate

Phase I: Exploration

Desk study

Initially, geological maps are reviewed to identify major rock formations and sedimentary basins. Aerial photography may be used to investigate landscape features, such as faults or anticlines, that indicate basin formation.

Aerial surveys

As with mineral exploration, additional data may be collected using satellite remote sensing and aerial geophysical surveys. Geophysical surveys, such as measurements of electrical conductivity, magnetism, natural radioactivity and gravity anomalies, may be conducted over a wide area to identify geological features indicating underlying petroleum. In addition, infrared imagery can help classify surface rock and highlight vegetation changes, which can indicate the presence of underlying oil reservoirs.

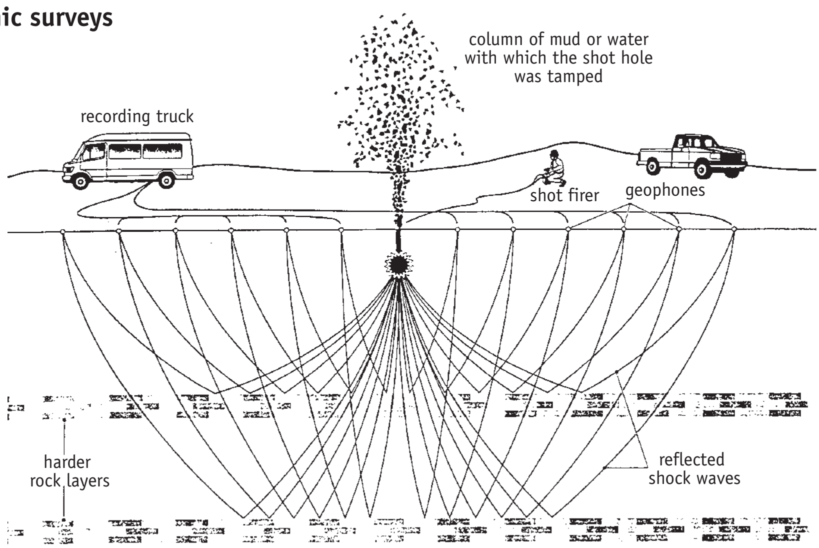
Seismic surveys

Local seismic surveys during oil exploration may use the following techniques:

- Explosive shot hole techniques involves detonating small charges from shallow boreholes along survey lines. Shock waves are reflected back from the underlying rock strata and measured using sensors (Figure 5). This information is used to map underground rock formations that indicate possible oil reservoirs. Although survey lines must be wide enough to allow access for the instruments and operators, they can be as narrow as 0.5–1 m, since instruments can be hand-carried.
- Vibroseis involves the use of three to five heavy vehicles, linked together by power and communication cables. The ground is subsonically vibrated and instruments record the reflected waves returning to the surface. Measurements are repeated every few metres. This technique can only be used on roads or other hard surfaces, such as grasslands, where vehicular access is possible. It is often environmentally preferable to the shot hole method, since the lower energy source disturbs wildlife less. Vegetation may have to be removed along an access track 3–4 m wide, however.

Figure 5. Seismic surveys

Source: Joint E&P Forum/UNEP. 1997. *Environmental Management in Oil and Gas Exploration and Production: An Overview of Issues and Management Approaches.*



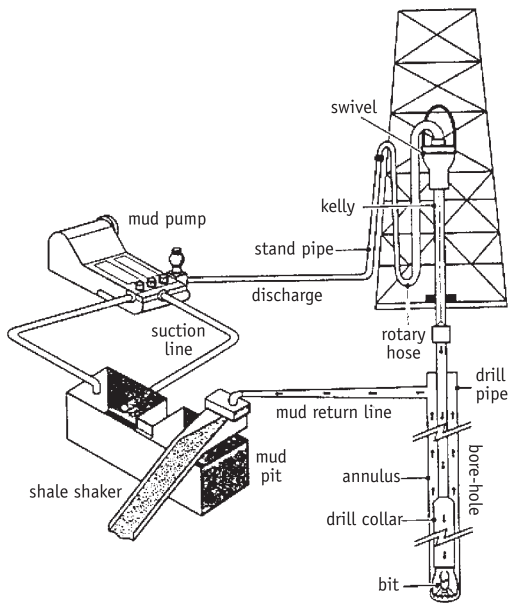
Exploration drilling

When exploratory surveys highlight a promising area, the next stage is to confirm the presence and extent of hydrocarbon resources by drilling one or more exploratory boreholes. Typically up to a dozen boreholes will be drilled over an area of several square km; drilling may last from one to three months. Sample cores are taken for analysis.

The site is prepared by banking the topsoil and subsoil around the perimeter. This will be replaced once the operation is complete. A pad is constructed to accommodate the drilling equipment and typically occupies 4,000–15,000 square m; the work camp occupies a smaller area, generally 100 square m. Drilling is usually carried out using a rotary drilling rig, supported by a derrick that houses the winch equipment, motor and power units (Figure 6). As the bore-hole gets deeper, new lengths of pipe are added; steel casing is cemented into place in completed sections, both for support and to prevent underground water or porous material from contamination by oil or drilling fluids.

Figure 6. Exploration drilling

Source: Joint E&P Forum/UNEP. 1997. *Environmental Management in Oil and Gas Exploration and Production: An Overview of Issues and Management Approaches.*



In order to cool the drill bit and flush out rock fragments, special water-based drilling mud (based upon bentonite, a naturally-occurring clay) is continuously circulated down the drill pipe and back up the borehole. A typical borehole 1,500 m in depth will require around 200,000 to 500,000 litres of drilling mud. The weight of the mud counterbalances underground pressure and prevents blowouts. Blowouts can also be prevented by using hydraulically operated steel rams, which close around the drill string and seal off the well. The drill site will require power generators, concrete-making equipment, drill-mud tanks and mixing pumps and a shale shaker for separating rock chips from drilling mud. Tanks for fuel, water and extracted oil, offices and security will be on site.

The drilling tests may generate oil, gas and water. Any gas produced is vented to the atmosphere and burned off. Recovered oil is stored in tanks and, if feasible, may be trucked off-site for sale; alternatively it may be burned on site in burn pits. Increasingly, the venting and burning of even small quantities of gas and oil may be considered environmentally unacceptable, and measures may be required to contain and dispose of vented gases and oils. Water produced by drilling activities may be highly saline or contaminated, and requires careful disposal.

Where oil is found, tests are carried out to establish flow rates and see if the oil will flow under its own pressure. Tests typically take one month. If exploratory drilling is successful, a small well-head valve is installed to cap the well. If the well is dry, then it is plugged with cement to prevent any migration of fluids from the well hole.

If the site is not considered commercially viable, the equipment, e.g. the drilling rig, is dismantled and moved for reuse at another site. The site should be left in a safe condition, rehabilitated and, where possible, restored to its original state. For further details on decommissioning, site rehabilitation and ecosystem restoration see section 2.2, Phase IV.

Phase II: Appraisal and feasibility studies

Prior to production, the company will carry out an appraisal to define the size and nature of the petroleum resource, and to determine how the production phase will proceed and whether it is economically feasible. The number of wells required depends on the consistency of the oil and the geological structure in which it is found. Deviated or directional drilling at an angle from the same drill site may be carried out to appraise adjacent areas. This reduces logistical problems, costs and environmental impact.

A preliminary feasibility study is generally based on a conceptual oil and gas production project evaluating whether the resource can be economically and technically extracted. A preliminary environmental appraisal needs to be carried out to identify and assess the potential environmental and social issues associated with production activities and closure plans, and to determine the need for protective and mitigation measures. If the preliminary feasibility study results in the decision to proceed, a full feasibility study is carried out. An environmental impact assessment (section 4.2.2) then needs to be developed to accompany the necessary consent applications.

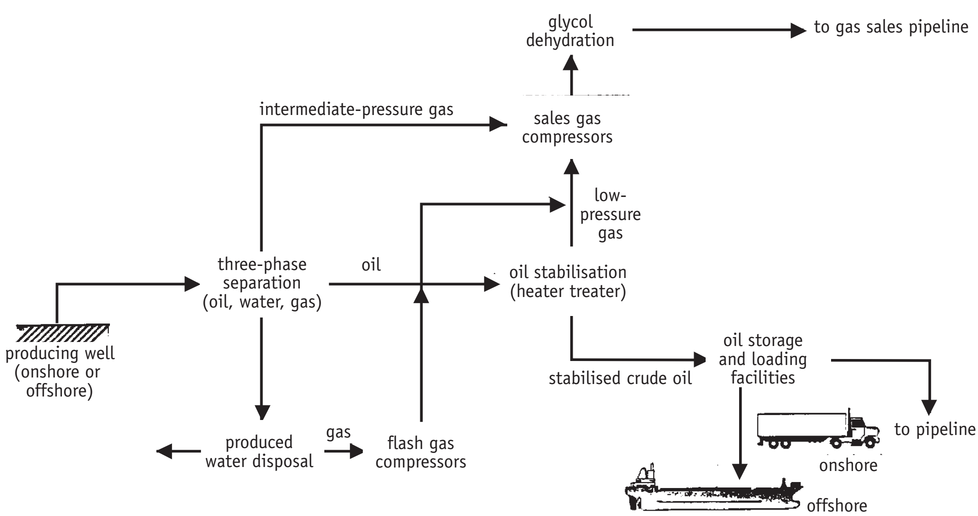
Phase III: Construction, production, processing and distribution

If a small reservoir is found, development may take place using one or more of the existing exploratory wells, with little additional input required. Multiple production wells are often drilled from one site to reduce overall costs. Where two or more sites tap a reservoir, a central production station may be used to collect and separate the oil, gas and water. The size and type of installation will depend on the reservoir's output, and its intended use, but it can cover a considerable area.

If sufficient quantities of gas are available, it may be used for commercial production; otherwise it can be pumped back into the reservoir to maintain pressure. Small quantities of gas will be vented or flared. Any water removed is either treated for disposal or re-injected into the reservoir. Once all of the oil has been recovered by natural pressure and pumping techniques (primary recovery), other recovery techniques may be used. These include water or gas injection (secondary recovery) and methods using chemicals, carbon dioxide, nitrogen or heat (tertiary recovery). In this way the maximum yield can be obtained from the drill site.

Apart from separation of the basic hydrocarbon products, processing and refining is rarely done on site. Additional oil and gas storage tanks will be required, unless a pipeline is to be used for exporting the products (Figure 7).

Figure 7. Crude-oil processing pathway



Source: Joint E&P Forum/UNEP. 1997. *Environmental Management in Oil and Gas Exploration and Production: An Overview of Issues and Management Approaches.*

Phase IV: Decommissioning, site rehabilitation and ecosystem restoration (see page 25)

2.4 General on-site requirements

All exploration and appraisal activities require support services. Although survey activities require less support than exploratory drilling and technical appraisal, they may have an unforeseen environmental impact because of their extensive nature. Drilling and technical appraisal is more focused and site-specific; the impacts can be predicted up front, and can be limited through effective management.

Access

Rigs and support equipment can be moved by land, water or air. Whichever method is used, a considerable logistical undertaking is required. For example, it may take 25-60 lorry loads to bring an oil-drilling rig to a site. Exploration drilling for minerals may involve only 2-3 trucks and occupy an area for 3-7 days. If the site is remote from roads and services, access routes will have to be constructed. Even where roads exist, they may not be adequate to carry the loads required by exploratory drilling. Site selection should therefore include consideration of access options and associated environmental impacts.

Facilities

Exploration sites in arid environments are remote and rarely have communications, power or water supplies nearby. Power generation facilities and fuel will have to be brought in. It is unlikely that water will be available on site; it will have to be brought there in tanker trucks.

A support camp for workers will be required. This usually consists of accommodation, canteen facilities, communications, vehicle maintenance and parking areas, fuel handling and storage areas and waste disposal facilities. The camp will generally be located upwind of the drill site and may occupy an area of around 1000 square m for appraisal operations. A support camp for oil drilling is usually larger than one for mineral drilling.

The accommodation requirements for the production phase are similar to those for exploration, except that there is more potential to house a permanent work force in the local area. Temporary accommodation for staff may be replaced with more long-term housing, and the supply of power and water may be brought in from outside, rather than relying on local generation and water sources. Highways and access roads may need improvements to carry the additional traffic, and more extensive communication networks may also need to be established.

Transporting products

The choice of how to transport commercial products — by road, rail or, in the case of hydrocarbon products, by pipeline — will depend on the location of the site. If large quantities of hydrocarbons are produced at a remote site, a network of pipelines is normally the most efficient way to transport the oil and gas to terminal facilities for distribution. Linear structures such as pipelines, roads and railways require a comprehensive environmental impact assessment before a decision can be made on the most appropriate mode of transport.

Chapter Three

Environmental impacts and recommendations

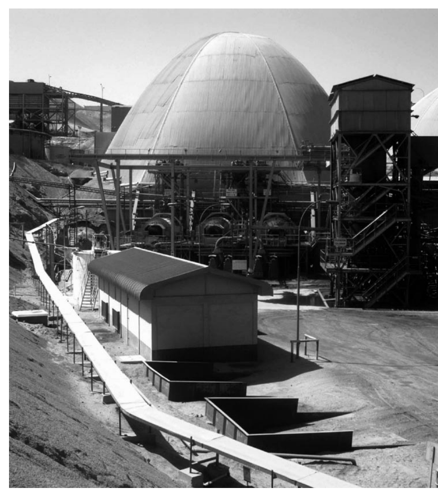
3.1 Physical environment

3.1.1 Air quality

Extractive industries operations in arid and semi-arid zones result in three main emissions: dust and particulates; combustion and greenhouse gas emissions; and process gas emissions.

Dust and particulates

By far the most common concern is the large amount of particulate matter generated by almost all aspects of mining, including blasting, earth- and rock-moving, milling and screening. The wind may also blow fine particles from drying tailings dams, and from drilling and construction activities, especially the building of access roads. The quantities of dust released will depend upon the character of the overburden and the ore. If the dust consists of relatively large particles it will settle out quickly. Finer particles remain in the air longer and may give rise to respiratory problems.



Dust containment in Atacama Desert, Chile.
Photo, Anglo American

The problem of dust is especially acute in arid zones; there is little natural rainfall to dampen the dust. Wind conditions tend to keep dust in the air longer, and carry it farther. The impact may be less significant, however, than in a more humid zone, where there are naturally fewer particulates in the air.

The application of strict air quality criteria suitable for an urban area may not be appropriate in an isolated desert area. Care must be taken, however, to assess the impact on communities in downwind areas and land-uses, since high particulate levels are damaging to health and agricultural production. In most cases the dust will be relatively inert, but it may contain hazardous trace elements, e.g. lead, arsenic, cadmium or nickel. Black particulates containing carbon will also be released from the combustion of oil and gas, e.g. in flares, and from coal-processing operations.

Combustion and greenhouse gases emissions

These are the main sources of combustion and greenhouse gas emissions:

- flaring and purging of gases from oil and gas wells, which release carbon dioxide (CO_2); if the oil contains a high level of sulphur, then sulphur oxides may be released into the atmosphere;
- the use of generators, vehicles and other equipment that release NO_x, CO_2, carbon monoxide and volatile organic compounds (VOCs); and
- leaking of gases, especially methane, from coal mines; methane from coal mines may account for up to ten percent of methane emissions worldwide, and is also a fugitive gas from oil and gas operations.

These gases can react with sunlight, causing local smog conditions, but this risk is quite low, since the quantities generated in isolated mining situations are relatively small. In view of the link between greenhouse gas emissions, climate change and desertification, however, mining and petroleum development companies in arid and semi-arid zones should make particular efforts to reduce emissions.

Process gas emissions

Process gas emissions include the following:

- sulphur dioxide emissions from copper and aluminium smelters;
- fluoride emissions from aluminium smelting; and
- perfluorinated carbon compounds from aluminium smelting and oil and gas extraction.

These hazardous gases can cause significant environmental damage, especially when they combine with rainfall to produce acid rain. Given the near-absence of rainfall in arid and semi-arid zones, however, localised effects will be less intense, although the regional contribution to acid rain from a large processing plant may be important.

RECOMMENDATIONS: Air quality

Dust caused by extractive industries operations is usually controlled by spraying roads and exposed areas with water. This may not be possible in more arid areas, however, since water is often not available in sufficient quantities. In such situations, operations should be planned to minimise the creation of dust, e.g. by restricting the area of operations when wind conditions are too strong. Abandoned extraction sites may be covered with a rock “mulch” to prevent dust from being recirculated.

The most significant target for emission reduction in the petroleum industry is flaring and venting. Improvements to control procedures, design and maintenance systems have led to a reduction in emissions. Technological improvements in valve designs have reduced the occurrence of fugitive emissions, and improvements in flare technology have increased combustion efficiency.

Technological changes to increase the efficiency and combustion performance of vehicles, pumps, compressors have also led to lower emissions. Regular and effective maintenance is essential to ensure that such improvements continue through the life of the operation.

Hazardous gas elements should be removed from process gas emissions wherever possible. Cleaning techniques include condensation, absorption, adsorption, filtration and scrubbing.

3.1.2 Soils

Disturbance of the soil profile during extractive industries development activities has a significant effect on physical, chemical and biological soil resources. The structure of arid soils (such as sands, topsoils and sub-surface layers) entails specialised features, such as desert varnish and desert pavements that are easily destroyed. Vehicle tracks can still be seen on some desert pavements many decades later.

Both physical removal and compaction by vehicle movements can damage the original soil structure, especially topsoils. This may also damage the biological resources, such as seeds, contained in them. Once damaged, soils are no longer able to perform their functions optimally in terms of movement of gases and solutions through the network of pores. This decreases the infiltration rate of rainwater, and reduces the soil's capacity to hold water. It may increase salinisation, as water moves to the surface carrying salts left behind as the water evaporates. The stripping of protective layers of soil and vegetation exposes underlying rocks and lower layers and can increase the risk of erosion from both wind and water. In arid and semi-arid areas, dry and poorly vegetated slopes are particularly vulnerable to erosion during the rainy season when rainfall events can be intense. Wind of only 15 km per hour can erode sand dunes through saltation.

Exploration drill site, Namibia.
Photo, Anglo American

The "erodability" of a particular rock is in relation to its type and origin, and to the mechanical and chemical weathering processes it will be subjected to on exposure. In arid and semi-arid lands, the scarcity of water generally slows the effects of chemical weathering. Wind and diurnal thermal expansion and contraction are more important factors. Ephemeral wadi flows and sheet runoff, resulting from intense precipitation events, can also result in surface water flows of enormous physical force, capable of transporting large sediment loads and causing significant erosion. Generally, the geologically older and consolidated rock types are more resistant to physical erosion.

Copper mine, Chile. Photo, Anglo American/ Phil Tanner

Poly-metallic, massive sulphide deposits may generate acid rock drainage (ARD). The release of other metals and contaminants will depend on the specific geochemistry and environmental conditions of the deposit. Such releases can have severe and persistent effects on vegetation and ground water. Under arid and semi-arid climatic conditions, characterised by extensive dry periods interspersed with rare high-rainfall events, ARD may not be apparent for some time.

Saline and sodic waste rock is often a particular problem in arid zones, where salt in the rock is of atmospheric origin, or is interstitial and cannot be predicted from the geology. If it is dumped with waste rock, the salt can be leached out from certain parts of the land form and concentrated in others. Although salinity tends to increase with depth within the weathered rock profile, high rates of evaporation in arid areas can lead to high salinity levels in the surface crust. Salinity levels can be complicated by ground water patterns. Fresh cuttings from drill cores can be used to determine relative salinity levels prior to mining. This allows overburden dumping sequences to be developed that will minimise the amount of salt near the surface.

RECOMMENDATIONS: Soils

Prior to project development all topsoil resources should be characterised and mapped in order to determine the following:

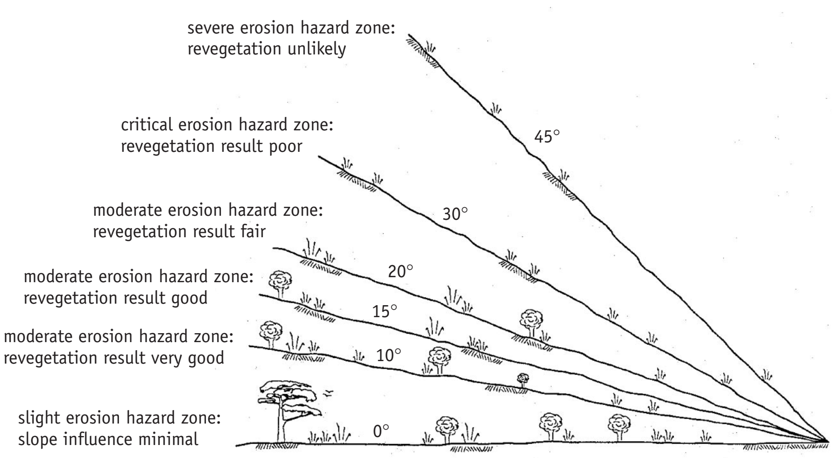
- quantity of soil;
- composition of vegetation;
- soil texture and depth; and
- pH, salinity and contaminant content.

It is important to determine the depth of topsoil to ensure that topsoil and subsoil are not mixed during land clearance. Topsoil removed should be cleared and harvested as areas are required for exploitation. Timely clearance will minimise storage times and surface exposure (Annex 2 illustrates topsoil harvesting techniques).

Erosion control

Control of erosion depends primarily on slope angle and slope length as well as soil type and rainfall/runoff characteristics. For example, long unbroken slopes allow rill and gully erosion to occur. General guidance suggests that slopes be constructed with a gradient of no greater than 20 degrees, with benches set at every 7–10 m of vertical height (Figure 8 illustrates the influence of slope on revegetation and erosion).

Figure 8. Influence of angle of slope on revegetation and erosion



Source: Department of Minerals and Energy, Western Australia. 1996. *Guidelines for Mining in Arid Environments*.

Several techniques have been identified to reduce the rate of saltation. Two general categories can be distinguished:

- Primary fixation uses mechanical means to stabilise wind-blown sand masses that threaten human settlements and infrastructure. These include fencing (placing a linear obstacle in the wind's path); mulch (spreading a material to evenly cover the soil, including rock or cut vegetation); and the aerodynamic method (streamlining the obstacle so that wind speed is not reduced and sand is not deposited, or alternatively, facilitating sand transport).
- Definitive fixation is achieved through the establishment of permanent plant cover.

Stabilisation is useful in an area where vegetation has been damaged or removed. If a dune has been reshaped and revegetated, then it is important to stabilise the surface quickly by protecting it from sand blasting and wind. A planting program should be employed to help seeds germinate and seedlings establish. The most commonly used techniques are brushes, mulches and cover crops, but non-vegetative methods such as liquid sprays and geotextiles may also be employed.

- Brushes and mulches act as surface wind barriers. They prevent the loss of further sand, and shelter seedlings. Coarse, fibrous materials are preferred as they are not blown away by the wind.
- Cover crops are best used where the sand surface needs to be held in place to establish secondary and tertiary species. They cannot withstand strong winds.
- Liquid sprays cement sand grains together, providing temporary stabilisation. This provides little protection to vegetation and is not able to trap wind-blown sand.
- Geotextiles help stabilise the soil and retain water while allowing seedling growth. They can only withstand a small build-up of sand, however, and generally require additional protection.

Slope stabilisation techniques such as hydro-mulching are not recommended for arid and semi-arid lands, because they require frequent rainfall to establish the seeded crop. Further, plants of arid and semi-arid zones do not emerge well from the thick organic mulches used as bonding agents in hydro-mulching. Hydro-mulching slopes does not create the physical microclimates on which desert plants rely for establishment.

Characterisation of waste rock is important in determining broad options for surface stabilisation (usually revegetation or rock armouring) and site drainage. Waste rock can be characterised at an early stage by examining drill-hole geology and analysis and evaluating bulk sample cuttings, adits and old workings for information on waste rock types, chemical content and weathering patterns following exposure. The key characteristics to determine are erodability and chemical properties.

Revegetation can reduce soil erosion by wind and water and restore worked-out areas to semi-natural conditions. Baseline studies conducted during the site evaluation and planning phases determine the characteristics of the local plant communities, providing essential information for planning the revegetation programme:

- Seed derived from locally adapted plant populations should be used to ensure successful revegetation. An appropriate licence, or the use of specialised contractors and research institutes may be required to carry out seed harvesting.
- Trials should be carried out to establish density of plant cover, viability of the seed under different storage conditions, optimum conditions for germination and survival rates.

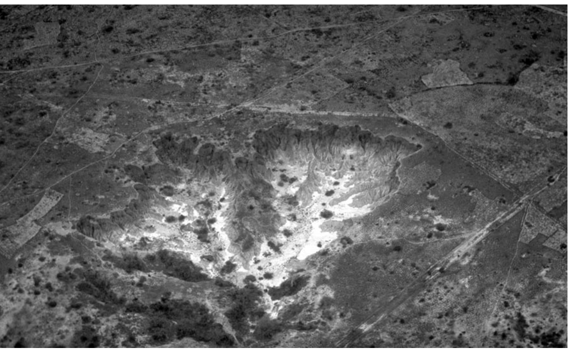
- Seeds should be cleaned prior to storage. Any extraneous material may harbour insects or microbes that could destroy the seed during storage. Such material also increases the volume to be stored and broadcast and compromises the estimate of quantities in the sowing mix.
- Seeds need to be thoroughly air-dried before being stored in insect-resistant containers. Napthalene crystals can be used to repel insects within the storage area.
- The optimum time for sowing will depend upon the local bio-climatic conditions. As rainfall is generally unpredictable it may be necessary to be prepared for opportunistic sowing.
- To ensure that seed is not buried below its germination depth or affected by salt, the area to be vegetated should, if possible, receive at least one significant rainfall prior to sowing. Where soil salinity is a problem, it may take a few years for the salt to leach out sufficiently for plants to become established.
- If slopes are too steep or rough to use spreading machines to broadcast seed, seeding can be done by hand.
- Since supplies of local seed may be limited it is important that application rates are worked out precisely to avoid waste.
- Seed mixes can be blended with bulking materials such as fine sand, chaff, sawdust, vermiculite, gypsum or fertiliser to aid dispersal.

Mycorrhizae are a natural component of soil ecosystems. They can increase phosphorus uptake; this improves vegetation growth rates and plant diversity by increasing the opportunity for higher dependent plants to become established. To retain the maximum amount of mycorrhizae in stored topsoil, the stockpiles should not be more than one metre high. Local fungi that are effective in increasing uptake in soils can be selected and prepared in an effective inoculum suitable for field application. This can be done by growing a small area of cover crop, collecting and cutting root sections, then spreading and burying the cuttings over areas where topsoil has recently been applied.

Bioremediation of contaminated soils uses living organisms (usually bacteria, fungi, actinomycetes, cyanobacteria and, to a lesser extent, plants) to reduce or eliminate toxic pollutants. These organisms may occur naturally or be cultivated in a laboratory. They either consume the organic contaminants or assimilate harmful compounds, such as heavy metals, from the surrounding area, rendering it virtually contaminant-free. Bioremediation harnesses this natural process by promoting the growth of these organisms (Annex 3 illustrates bioremediation techniques).

3.1.3 Landscapes

Arid and semi-arid landscapes often contain unique geomorphologic features. Because of the lack of dense vegetation, vistas across vast expanses of relatively flat land will reveal alterations in topography and land forms as a result of mining and petroleum operations. These alterations include excavations, waste disposal heaps, tailings dams, access roads and pipeline transmission routes. The buildings and equipment of underground mines and drilling rigs will also stand out in sparsely vegetated landscapes. Underground mines may cause subsidence over a much larger area than the surface footprint of the mining operation. Placer mining can cover very large areas of land; even artisanal or small-scale placer operations leave their mark on the landscape.



Abandoned mining pit, Central Angola.
Photo, CIDA/Bruce Paton

The slow regeneration of vegetation after mining or petroleum production in arid and semi-arid zones means that changes to landscape features as a result of mining often remain visible for a long time. Erosion forces can be very strong in arid climates and there is an increased risk of waste of impoundments, surface materials and exposed bedrock.

RECOMMENDATIONS: Landscapes

Rehabilitation and ecosystem restoration requires great attention in arid and semi-arid lands, and needs to be an integral part of the environmental management planning of any extractive industries operation. Rehabilitation and restoration plans need to be agreed to by local authorities and communities prior to extractive development activities.

National parks and other forms of protected areas (PAs) have been established under law. IUCN – The World Conservation Union has developed categories of management for PAs that are widely accepted. Recommendation 2.82 (Protection and conservation of biological diversity of protected areas from the negative impacts of mining and exploration) was adopted by IUCN's members at their Second World Conservation Congress (Amman, Jordan; October 2000). It calls for state members of IUCN to prohibit by law all exploration and extraction of mineral resources in PAs that correspond to IUCN Protected Areas Management Categories I to IV. For categories V and VI, exploration and minimal localised extraction may be acceptable if compatible with the objectives of the protected area. In those cases an environmental impact assessment must be carried out and the operation should be subject to strict operating, monitoring and after-use restoration conditions. The recommendation also calls for any changes to boundaries (i.e. to accommodate exploration and extraction activities) to be subject to a process at least as rigorous as that used to designate the PA. Additional PAs may be established alongside the mine or oil and gas field to protect those biological resources that the operation may threaten.

Northern Cape, South Africa.
Photo, Anglo American/Phil Tanner

3.1.4 Water resources

Hydrological and hydrogeological changes

Hydrological and hydrogeological (aquifers and recharge regimes) changes result from modification of existing drainage patterns due to changes in the soil conditions, e.g. disturbance of vegetation, compaction due to vehicle movements, or topsoil and subsoil removal and/or accumulation. Once the mine is operational long-term changes may develop, particularly where deep drainage and mine dewatering is necessary. Mine dewatering will tend to increase the rate at which the water table sinks within the locality, especially if the mine water is discharged to a different hydrological basin.

Mining and oil and gas operations often require significant quantities of water for dust suppression, ore separation, processing and for consumption. This can cause a strong demand for water in an area where resources are extremely scarce. Incoming businesses and service industries will further increase the demand for water.

In some cases, water may have to be transported or piped in. In other cases, it may be necessary to drill deep boreholes to tap into underground resources. This may lower the water table. A further cause of depletion may be the induced demand, created by developments around the site, which is likely to persist well beyond the life of the project (Table 5).

Table 5. Sources of freshwater and associated implications of abstraction

Source	Implications of abstraction
rainwater harvesting (from roofs, slopes, check dams in wadi beds)	• can decrease ground water recharge • may affect downstream users along wadis, e.g. farmers dependent on periods of high rainfall for irrigation
surface waters (rivers, lakes or wetlands)	• competes with other local and downstream requirements for water supply, e.g. livestock and agriculture • may have consequences for nature conservation, wetland habitats and wildlife
desalination or treatment of saline or brackish water	• creates hyper-saline residue
imported water (by canal, pipeline or tanker)	• rising water table from discharge, leaks and associated waste water could increase salinity • effects associated with infrastructure, potentially non-sustainable depletion from other areas • increased access for local communities to a source that would not normally be available
ground water derived from rechargeable aquifers	• potential depletion of resource at a faster rate than its recharge • lowering of the water table, which could derogate local ground water supplies (e.g. hand-dug wells) surface waters and wetlands
ground water derived from fossil aquifers	• depletion of a non-renewable resource of very high quality

Water pollution

The increase in water use in all areas of extractive industries operations will heighten the risks of pollution and contamination in surface and ground waters:

- Pumping for dewatering mines may lead to acid mine drainage (AMD) and heavy metal contamination. In certain areas this water may be saline or hyper-saline; releasing it can contaminate large areas and degrade vegetation. AMD will eventually find its way into surface and ground water systems.
- Leachate migration from tailings dams may also cause severe damage to surface and underground waters. In the event of extreme rainstorms and flash floods, which arid areas occasionally experience, tailings dams may be overtopped or broken. This releases highly contaminated water and sediments into water courses.
- Physical and chemical extraction processes produce effluents that can both contaminate and release sediments into watercourses, especially after rainstorms.

- During exploration drilling, there is a potential threat of release of oil and lubricants. Because of the uncertainties of downhole conditions, exploration drilling can involve risks of accidental spillage and blowouts.
- Sewage and domestic wastes from staff accommodation facilities and towns pose another risk of water pollution.

RECOMMENDATIONS: Water resources

Measures to maximise water conservation include the following:

- creating diversion channels around areas of disturbance;
- harvesting rainfall, e.g. through the use of check dams or other means;
- reinstating the surface hydrological regime on completion of project;
- designing and implementing water flow control systems in areas of high permeability.
- avoiding a high number of operations in areas of low permeability;
- retaining ground water recharge systems by minimising surface changes (e.g. sealing and lining tailings areas and waste lagoons, and reducing waste volumes);
- minimising the need for dewatering through sealing of workings and other actions;
- decommissioning of dewatering wells and ground water removal systems at the rehabilitation/restoration phase to eliminate the removal of water from aquifers after the project ends;
- increasing the potential for ground water recharge through the creation of swamp and vegetated areas;
- in areas of high permeability, ensuring that backfilling maintains aquifer structure e.g. by removal of plugs, cut-offs etc., and enhancing hydraulic activity after mining e.g. through hydro-fracturing of grouted areas; and
- in areas of low permeability, backfilling with lower permeability material, plugging conduits, construction of bulkheads etc.

Extractive industries developments may generate a wide range of wastes that can pollute water resources. These wastes should be included in a waste management plan (Annex 4 illustrates the steps in preparing a waste management plan). There are three principal issues in managing the impacts on surface or ground water quality.

Waste disposal, copper mine, Chile.
Photo, Anglo American/Phil Tanner

Source control prevents contaminants from leaving their source. This can be achieved in the following ways:

- minimising waste generation by segregating potentially contaminating material for separate disposal, and choosing techniques with lower effluent toxicity;
- containment through the use of liners, membranes and walls, or by controlling water gradients in the vicinity of the contaminating material;
- modification of contaminant through neutralisation, volatilisation or other chemical processes; or
- removal through reprocessing or disposal at an appropriate waste disposal site.

Pathway control intercepts or modifies waste water as it passes from its source to the receptor, by means of the following:

- pump and treatment;
- in situ treatment; or
- natural treatment (dilution, neutralisation, biodegradation etc.) in the aquifer or surface water systems.

Remediation at receptor applies primarily to ground water resources. It can be achieved through treatment prior to use; for example, at wells or point of emergence of ground water to the surface water system where it may affect the ecosystem.

Great care needs to be taken in acid mine drainage (AMD) disposal. These are the methods commonly used to minimise the risks associated with AMD:

- treatment through chemical or passive methods to neutralise acidity, followed by separation of sludge and water in settlement ponds; and
- abatement through isolation from water or oxygen, inhibition of iron-oxidising bacteria, or incorporation of alkalinity.

Annex 5 provides a general overview of the construction of a waste dump.

3.2 Biological environment

3.2.1 Flora

Many areas in arid and semi-arid zones have remained untouched by human activities for centuries due to their remoteness and extreme climate conditions. Access as a result of mining and oil and gas operations can disturb these ecosystems. Changes in the vegetation cover, whether for site clearance and vehicle movement during exploration activities, or caused by large-scale land clearance for production operations, affects the soil and can result in habitat and species loss.

Increased demand for firewood for cooking and water heating for the staff and workers of isolated mines and petroleum sites puts further pressure on local vegetation. In addition, mining and oil companies tend to introduce exotic flora when they landscape the grounds of offices and facilities. Introducing non-native exotic plants can damage the ecological balance of arid and semi-arid ecosystems, due to their potential invasiveness. In addition, if they are not adapted to arid conditions, they may require excessive amounts of water.

RECOMMENDATIONS: Flora

Conservation of seeds of local plant species and of topsoil containing high proportion of these is an important aspect of rehabilitation and ecosystem restoration. Where the ecosystem and its flora and fauna are considered to be particularly unique, the introduction of exotics with potential of becoming invasive should not be attempted.

Use of firewood from arid and semi-arid lands should be avoided. If firewood is required, it should be brought in from outside, rather than relying upon local sources.

3.2.2 Fauna

Extractive industries operations in arid and semi-arid lands have considerable potential to disturb local fauna, through habitat encroachment, noise from blasting and other activities, and reconnaissance work. Although the fauna of arid and semi-arid lands is well adapted to the scarcity of water, both vertebrate and invertebrate fauna will be attracted to a site when water becomes more freely available there, e.g. through discharges of mine waters, effluents and leachates. This water may be contaminated and could increase mortality among local wildlife populations.

Wetlands in arid and semi-arid zones are important as habitat and a source of water for livestock and wildlife. Thus, protection of wetlands from depletion — as a result of lowering the water table, and from pollution by effluents and contaminants from mining or oil and gas operations — is particularly important.

The sudden influx of large numbers of mine and petroleum workers may increase the demand for bushmeat. Intensified hunting and poaching will put further pressure on wildlife populations, and threaten some populations with local extinction.

RECOMMENDATIONS: Fauna

Wildlife surveys need to be carried out. If endemic or threatened species are identified, special protection measures (such as avoiding habitats and reducing disturbances) must be considered. Extractive industries development activities may need to be restricted during the breeding seasons of larger mammals and sensitive bird and bat species. Mining and petroleum companies should also develop strict policies for controlling hunting by workers.

3.3 Socio-cultural environment

3.3.1 Populations and settlements

Exploration and production activities can have considerable effects, both adverse and beneficial, on local communities. Existing settlements and resources used by local people may be close to the mine or oilfield site.

Relocating settlements will disturb the social infrastructure; however, it can also be an opportunity to provide new infrastructure — roads, utilities and schools — as well as access to goods and services hitherto unobtainable in the area.

The presence of a new employer can attract job-seekers to the area. Despite the accommodation provided for workers, shanty-towns may develop, putting a stress on both new and existing facilities and services. The same concern applies to concentrations of artisanal miners attracted to one small area.

RECOMMENDATIONS: Socio-cultural environment

Consultation and studies will be required to assess the potential need to relocate such settlements. Attention should be paid to choosing relocation sites that are acceptable to local people and not affected by environmental effects from the site, e.g. windblown dust, contaminated surface or ground water, and noise.

Mining and oil companies should consult with local communities to ensure that new facilities are both wanted and appropriate. The companies should also develop strict policies for managing job-seekers and the growth of shanty-towns.

3.3.2 Economic impacts

Although the discovery and exploitation of mineral and oil resources in arid and semi-arid zones can bring much-needed economic development benefits to an area, local communities may not be best able to respond to these opportunities. They also may not be competitive with incoming job-seekers for the new employment opportunities.

In addition, there may be losses of land and other natural resources upon which local communities depend, which threatens the security of their livelihoods. The increased demand for housing, food and commodities will push up market costs, pricing local residents out of the market.

The boom-and-bust scenarios of mining and oil and gas towns have occurred throughout the world. The social and economic aspects of extractive industries operations are shown in Box 2.

Box 2. Socio-economic aspects of extractive industries operations

Losses and pressures
- land used for operation site and infrastructure
- loss of traditional lands for agriculture and livestock
- loss of access to natural resources for collection of wild products
- loss of access to or destruction of sites of religious, cultural or archaeological value
- exclusion from grazing and migration routes
- changes in social-cultural practices as a result of incoming workers and job-seekers
- pressure on firewood, food and water supplies
- increased prices for housing, food and commodities
- increased health risks from pollution and contamination, and from migrant workers

Opportunities
- access to infrastructure, water and energy sources provided by company
- equitable access to educational, medical resources and facilities
- employment opportunities
- opportunities for agriculture, small businesses and service suppliers

RECOMMENDATIONS: Economic impacts

Mining and petroleum companies should work together with government agencies, local government and communities to build local capacities for economic development. Future use and the development of an area used by extractive industries needs to be decided in collaboration with the local population before decisions are made regarding restoration.

3.3.3 Human rights and equity considerations

The development of a mine or petroleum interventions can provide a breeding ground for conflicts between the developer and the local communities and interest groups. Local concerns may be overlooked and the rights of indigenous people may be neglected. Nomadic people may have temporarily moved away from the area at the time decisions are made, and be left out of the consultation process. Land tenure is complex in such situations and indigenous peoples may have traditional rights to both land and resources. Conflict and social unrest can be triggered if local people's rights are not respected.

RECOMMENDATIONS: Human rights and equity considerations

Mineral and petroleum companies must take care to ensure equitable access to opportunities for local communities, and provide adequate compensation packages for loss of lands and rights of access, and recognition of rights to natural resources. Government agencies responsible for employment, social welfare, land tenure and human rights should monitor the adequacy and effectiveness of implementation of employment and compensation schemes.

Liaison with local communities is a critical factor in ensuring a successful, mining or petroleum development that is not beset by conflicts. Liaison contributes to the company's corporate responsibility for socially sound development, human rights requirements and the health and safety of employees and the surrounding communities. It is essential that local communities appreciate both the benefits and the negative impacts of the development, both in the short and long term, and understand how they may be involved. Three levels of the participatory process can be undertaken during development:

- provision of information about the extractive industries development activities;
- consultation, whereby the stakeholders' opinions are sought and taken into account by decision-makers;
- full participation by all stakeholders, who share responsibility for making decisions about the management of the environment and natural resources, and who may take responsibility for monitoring the implementation of these decisions.

Communication between the exploration or development company and the local community is a key element to building the trust of local stakeholders. It includes the following:

- use of local languages is essential for effective communication;
- explanation of the benefits and possible negative impacts of the development on the local community, both in terms of local employment, community development and infrastructure provision, training, and any present and future impacts upon the natural resources and the livelihoods of the communities;
- information about the risks of emergencies in order to develop suitable emergency responses;

- building the capacity of different stakeholders to fulfil their different roles more effectively; and
- regular reporting, including decisions, operational issues and stakeholder concerns.

3.3.4 Occupational and public health

Mining operations may use or expose hazardous materials, which find their way into the environment and contaminate soils and water bodies. This can lead to greater exposure to hazardous materials for both the work force and the local population. The noise and vibrations from blasting and earth-moving equipment and vehicles may also cause considerable disturbance. The introduction of a migrant work force into an area where local or indigenous communities have been relatively isolated puts the communities at risk from exposure to diseases brought in by the work force. Unwanted pregnancies and sexually transmitted diseases often increase among local people in these circumstances.

RECOMMENDATIONS: Occupational and public health

Extractive industries need to ensure the safety, hygiene and occupational health of local communities and workers. Relevant issues and measures are described in the many industrial reference works; of particular importance in arid and semi-arid zones are heat stress, dehydration, dust and fire hazards.

Chapter Four

Environmental planning and management

This chapter outlines the key institutional frameworks pertinent to planning and management of mining and petroleum development (Figure 9). Relevant institutions involved at the international, national and local levels, and their roles and the relationships are described briefly. This chapter also lists the main international conventions and national policy and legal frameworks that need to be considered in the exploration and exploitation of natural resources. It further discusses the main planning and management tools, i.e. strategic environmental assessment, environmental impact assessment, environmental management plans including contingency and rehabilitation/restoration plans, and monitoring and reporting.

Figure 9. Institutional framework for extractive industries

4.1 Institutional frameworks

4.1.1 Government institutions

A number of government departments are concerned with environmental planning and management of extractive industries development activities in arid and semi-arid regions. Each country has institutions with similar responsibilities for administering government policies, although these institutions may not all have the same name. They can be grouped into four main categories: concession/permitting agencies; planning agencies; environment and natural resource management agencies; and monitoring agencies.

Concession/permitting agencies

Concession agencies, such as Departments of Mines, Minerals and Hydrocarbon Resources, are responsible for granting permits to extractive industries companies. They may also monitor and audit the operations of the concession holders (see also monitoring agencies).

Planning agencies

Departments of Planning, Land-use and Urban Planning are concerned with changes in land-use, both during operations and afterwards. Planning for mining and oil production also involves coordination with other sectors, such as transport, energy, housing and community affairs, and labour.

Environment and natural resource management agencies

Government agencies such as Departments of Environment, Water Resources, Wildlife, Forest, Agriculture, Fisheries, and Protected Areas are responsible for implementing and enforcing environmental policies in their respective sectors. They may also be the focal points for any international environment conventions ratified by their governments.

Monitoring agencies

Many of the above agencies will have responsibilities for monitoring the different policies or activities within their jurisdictions. Monitoring the environmental and social issues related to extractive industries development activities in arid and semi-arid regions may be limited by the capacity of these departments to deploy staff. This is a particular issue in the more isolated areas where mines and oil operations are often located. Appropriate monitoring and testing equipment and vehicles may also be scarce. In some cases monitoring may be contracted out to university departments or research organisations. Rarely will a single organisation coordinate the monitoring results, with a complete evaluation of environmental performance. An inter-agency commission or steering committee — with representatives from concerned government departments, agencies, local government and adjacent communities — may provide a mechanism for coordinated monitoring of extractive industries development activities.

Increasingly, many countries are moving to devolve powers and responsibilities to the appropriate local level. The planning and environmental and natural resource management and monitoring functions listed above are replicated at the local level. Local government departments should be involved in any decisions to establish, manage or monitor extractive industries development activities in their area.

4.1.2 Private sector

International and large-scale national companies

The mining and oil industries are dominated by a few international companies that operate globally. A small number of large-scale companies may operate nationally or regionally. Junior companies or national subsidiaries of international companies may manage operations nationally.

International companies are usually at the forefront of the development of technologies for addressing environmental sustainability concerns associated with the mining and petroleum sectors. This is partly because they have the resources to do so, and partly because international public opinion and shareholders demand it. Although these organisations have environmental policies in place, the application of these policies may differ depending upon national requirements.

Medium- and small-scale companies

Medium- and small-scale mining companies can make significant contributions to national development objectives by encouraging indigenous entrepreneurship and industrialisation. Small-scale mining is labour-intensive and has a considerable impact in providing employment. Small mines provide an opportunity for transforming unskilled labour into semi-skilled and skilled labour. In addition, small mines require only a fraction of the capital required by larger operations and can be brought into operation much more speedily.

Specialist companies, contractors and service providers

Both the mining and oil and gas sectors have many specialist companies that provide services. These include survey and exploration, drilling, provision of machinery and equipment, and construction. Some specialist companies operate globally, but the majority of them provide their services at the national or local levels.

Artisanal mining

Artisanal mining is carried out by individuals, and ranges from part-time prospecting for precious stones and minerals, through to concentrations of people, usually poor, working in a particular area. This informal mining sector has caused considerable concern because of the serious health risks it poses, and the environmental damage it causes. The discovery of accessible mineral resources can attract large numbers of people to a site, making it very difficult to control or manage. Various attempts have been made to address these issues, such as the support of small-scale mining cooperatives, and the provision of training, technical advice and awareness-raising about environmental and health protection.

Banks and financing agencies

Mining and oil companies require financing through credits and grant allocations. While many international banks now require environmental impact assessments and environmental management plans, national banks and funding agencies may not. It is important that all banks and funding agencies ensure that environmental and social issues associated with the extractive industries development are integrated into the investment scheme and that appropriate measures are incorporated to mitigate adverse impacts. Development banks such as the World Bank and institutions operating at the regional level (Asian Development Bank, Inter-American Development Bank, etc.) have private-sector financing departments.

4.1.3 Civil society

Communities

Local communities have an important responsibility in determining which activities are undertaken in their area. They must be key stakeholders in the planning, development and closure processes. Local knowledge about natural resources and their use is fundamental to sustainable development and environmental management. Formal representation should be achieved through traditional leaders or elected local-government representatives. Consultation should not be limited to these individuals, however, and other community representatives, such as teachers, doctors and religious leaders, should also be included. Different groups in the community — indigenous peoples, ethnic minorities, women, youth, farmers, cooperatives and community businesses — will provide different perspectives on the proposed development and their concerns must be taken into account. Specific interests may have more formal representation by community-based organisations (CBOs) that have been set up for indigenous peoples, women's and youth groups within the community.

Non-governmental organisations

A large number of international and national non-governmental organisations (NGOs) exist, with specific objectives covering issues such as sustainable development, conservation and the environment, equity, human rights and indigenous peoples. These organisations work at all levels, from international policies to national advocacy and the support of local communities. NGOs can bring significant pressure to bear when these issues are raised as a result of mining and petroleum developments. In addition, NGOs may be contracted by governments or supported by external donors to independently monitor such developments.

Universities and research organisations

In many countries a number of university departments and research organisations have been established to study dryland agricultural systems and ecosystems. Research may include topics such as agricultural development for specially adapted crops, irrigation, geology and hydrology, biodiversity of dryland ecosystems and climate change. These organisations represent a significant body of knowledge, both about local conditions and the environmental and social impacts of development, and they may be contracted to carry out baseline studies and monitoring.

4.1.4 International organisations and associations

United Nations organisations

A number of the United Nations organisations have responsibilities related to arid and semi-arid regions, the fight against desertification and the encouragement of sustainable development. These include the United Nations Office to Combat Desertification and Drought (UNSO), the United Nations Development Programme (UNDP), the United Nations Environmental Programme (UNEP), and the United Nations Industrial Development Organisation (UNIDO). The International Fund for Agricultural Development (IFAD) hosts the Global Mechanism (GM) of the United Nations Convention to Combat Desertification (UNCCD), promoting actions that lead to the mobilization and channelling of financial resources to developing countries affected by drought and desertification.

International private sector associations

Within the oil and mining industries there are a number of international associations, which have increasingly addressed environmental issues on behalf of their respective sectors. These include the International Petroleum Industry Environment Conservation Association (IPIECA) and the International Association of Oil and Gas Producers (OGP), formerly known as the Oil Industry International Exploration and Production Forum (E&P Forum). These groups have produced a number of environmental guidelines in collaboration with other international organisations. In 1991, the International Council on Metals and the Environment (ICME) was formed to promote sound environmental policies and practices. Now known as the International Council on Mining and Metals (ICMM), it aims to be the global voice of the world's mining and minerals industries, developing their sustainable development position and promoting best practice on sustainable development issues within the industries.

International organisations and key initiatives

A number of international organisations and networks also have environmental and sustainable development objectives and initiatives relevant to extractive industries development activities in arid and semi-arid regions. These include IUCN – The World Conservation Union, the International Institute for Environment and Development (IIED), the World Wide Fund for Nature (WWF), Conservation International (CI) and the World Business Council for Sustainable Development (WBCSD).

The Mining, Minerals and Sustainable Development (MMSD) initiative, which began in April 2000, was an independent two-year process of consultation and research aimed at understanding how to maximise the mining and minerals sector's contribution to sustainable development at the global, national, regional and local levels. It culminated in a final report and a series of working papers and created a dialogue process for the future. It was undertaken by IIED under contract to WBCSD and was supported by the Global Mining Initiative.

The small-scale mining sector has also been active in developing countries; the United Nations Department for Technical Cooperation and Development (UNDTCD) has organised several regional conferences on this subject. An international non-profit agency for small-scale mining — Small Mining International (SMI) — was established in Montreal, Canada in 1989. This organisation aims to strengthen and support the small-mining sector as an aid to rural social and economic development. Several countries, such as India, Ghana, Bolivia, Brazil and Zimbabwe, have organisations that promote and provide technical support to the small-mining sector.

The Communities and Small-scale Mining (CASM) initiative was launched in March 2001 as a multi-donor networking and coordination facility. It aims to reduce poverty by supporting the integrated sustainable development of communities affected by or involved in artisanal and small-scale mining in developing countries.

4.1.5 International conventions, national policies and legislation

International conventions

A number of international conventions are relevant to extractive industries development activities in arid and semi-arid regions. Some of them evolved out of the 1992 Earth Summit in Rio de Janeiro and the Agenda 21 process; a few are more longstanding environmental conventions (other relevant international conventions are listed in Box 3).

The United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) is implemented through national action programmes (NAPs). These programmes are developed with the participation of local communities. National governments, by their accession to UNCCD, commit themselves to providing an enabling environment through the removal of legislative and policy obstacles, the introduction of land reforms that provide greater security of tenure, and the development of institutions for resolving conflicts relating to land use and resources. One of UNCCD's important principles is that efforts to combat desertification should be fully integrated into other development programmes.

UNCCD has regional action programmes in Africa, Asia, Latin America and the Caribbean, the Northern Mediterranean, and Central and Eastern Europe. They are oriented toward the specific regional and sub-regional conditions and requirements of the member states. Programmes address poverty reduction, migration and food security (Africa), agro-forestry and soil conservation, rangeland management and strengthening capacities for drought impact mitigation (Asia), monitoring and evaluation of land degradation (Latin America), and the protection of land that has not yet been significantly degraded (the Northern Mediterranean). The latter recognises that modern economies also contribute to desertification and land degradation through, for example, the contamination of soils by metals and changes to surface and ground waters.

The Convention on Biological Diversity (CBD) has three main goals: the conservation of biodiversity; sustainable use of the components of biodiversity; and sharing the benefits that arise from the commercial and other use of genetic resources in a fair and equitable way. It recognises that responsibility for biodiversity conservation rests largely with the countries themselves, and that private companies, land-owners, fishers and farmers are responsible for most of the actions that affect biodiversity. Under the CBD, governments undertake to prepare and implement national biodiversity strategies and action plans and integrate them into national environment and development plans. The convention also recognises that traditional and indigenous communities depend on biological resources, and that they possess traditional knowledge and practices that relate to the conservation and sustainable use of biodiversity.

The UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol provide the foundation for intergovernmental efforts to address the problem of potentially irreversible climate change resulting from rising concentrations of greenhouse gases in the earth's atmosphere. These gases are caused by the economic and demographic growth of the last two centuries. The UNFCCC sets the ultimate objective of stabilising atmospheric concentrations of these gases at levels that would prevent "dangerous" human interference with the climate system. Parties to the convention are subject to a set of general commitments, and are divided into two main groups: the industrialised countries, which have historically contributed the most to climate change (Annex I Parties), and those countries which have not (non-Annex I Parties). Some of the countries in the first group are also included in Annex II; they have a special responsibility to provide additional financial resources to developing countries to help them tackle climate change. The convention identifies two groups of vulnerable countries: those that face the adverse effects of climate change, e.g. low-lying island nations; and oil-exporting states that are threatened by the economic repercussions of response measures to climate change.

The Kyoto Protocol sets targets for the emissions of the six main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). It establishes mechanisms such as emission offsets to remove greenhouse gases from the atmosphere by creating carbon "sinks" through initiatives such as afforestation, forest management, cropland management and grazing land management. The protocol also establishes three innovative mechanisms known as joint implementation, the clean development mechanism and emissions trading.

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar) (1971) provides the framework for international cooperation in the conservation and wise use of wetland biomes. Wetlands occupy the transitional zone between permanently wet and generally dry environments; in arid and semi-arid regions, they are especially important habitats and concentration points for wildlife. The Ramsar Convention has a particular focus on wetlands that are important habitats for migratory waterfowl species. Contracting Parties are obliged to list and protect at least one Wetland Site of International Importance in their countries, include wetland conservation within national land-use planning and promote the wise use of wetlands.

The Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS) (1979) aims to conserve avian, marine and terrestrial migratory species. It provides a framework within which parties may act to conserve migratory species and their habitats. They can adopt strict protection measures for those migratory species categorised as being in danger of extinction in all or a significant proportion of their range. Parties also develop agreements for the conservation and management of migratory species that have an unfavourable conservation status, and undertake joint research and monitoring activities. Arid land species that have been highlighted under such agreements include the Great Bustard, the Houbara Bustard and the Sahelo-Saharan Antelope. The convention is relevant to mining and petroleum companies because it includes the protection of these species from hunting by company staff and site workers.

UNESCO's Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention) (1972) defines the kind of natural and cultural sites that can be considered for inclusion in the World Heritage List. It also sets out the duties of states in identifying potential sites, and their role in protecting and preserving these sites. Mining and petroleum developments should be aware of any existing or potential World Heritage Sites in the vicinity, and take steps to protect them from any adverse environmental impacts that arise from development activities. In 2000, UNESCO and ICME organised a technical workshop on world heritage and mining; it recommended that mining and conservation specialists work together, and highlighted the roles of the State Parties, World Heritage Mining Agencies and the mining industry in coordinating the conservation of these sites with the development of mineral exploration and extraction.

Chapter 26 of Agenda 21 and the **International Labour Organisation (ILO) Convention (No.169) Concerning Indigenous and Tribal Peoples in Independent Countries (1989)** recognise the link between global environmental change and the rights of indigenous populations, and the close relationship between indigenous peoples' cultural and economic situations and their environment.

Box 3. Other relevant international conventions

Convention on International Trade in Endangered Species of Wild Fauna and Flora. (CITES), 1973. Amended 1979, 1983

Montreal Protocol on Substances that Deplete the Ozone Layer, 1987

Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention), 1989

International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990

Convention on Environmental Impact Assessment in a Transboundary Context, 1991

Convention on Protection and Use of Transboundary Watercourses and International Lakes, 1992

Convention on the Transboundary Effects of Industrial Accidents, 1992

National policies and legislation

Many countries have basic environmental policies and legislation in place that relate to extractive industries development activities. There is a wide variation, however, in the coverage and enforceability of policy and legal frameworks, and the reader is advised to consult the national authorities for the details of specific countries' legislation. Typically, policies and legislation should address the following key areas:

- minerals and hydrocarbon resources (such as rules and regulations for prospecting and mining and for petroleum production, including systems for obtaining licences and concessions, and for monitoring operations);
- environmental protection and management (including requirements and guidelines for environmental impact assessment of proposed developments);
- water resources (including the regulation of water resource use, ground water abstraction, water pollution and effluent standards);
- air (including air pollution and emission standards);
- agriculture, livestock and forests (including soils and prevention of erosion);
- land-use planning;
- land tenure (determining rights of land ownership);
- community/traditional rights (including rights of access for cultural reasons and for the collection of wild products); and
- protected areas and biodiversity conservation.

Sometimes legislation and sectoral policies conflict with each other. There may be a hierarchy of legislation; in some countries, mining and petroleum activities have historically taken precedence over almost every other activity. This means that in the past mining and petroleum developments were undertaken as the preferred land-use in many areas without adequate environmental controls. Where this situation prevails in countries with arid and semi-arid zones, government policy and legislation should be changed to bring mining and oil production under appropriate environmental controls.

4.2 Key planning and management tools

4.2.1 Strategic environmental assessment

After a significant new mineral or petroleum resource is identified, but before specific details are planned, the government should carry out a strategic environmental assessment (SEA). The SEA should assess the region, including the following factors:

- baseline environmental conditions and the status of natural resources;
- identification of ecologically sensitive and protected areas;
- identification and description of communities and indigenous peoples;

- existing socio-economic conditions;
- existing economic activities and infrastructure;
- proposed developments, including longer-term scenarios and the cumulative development of a number of different mine or oil and gas sites;
- infrastructure and resources required to service these developments (roads, power and water);
- potential environmental and social impacts of the mining or petroleum development; and
- recommendations for zoning of land areas and limitations on development in the different zones.

The SEA thus provides a longer-term view of the environmental and social basis for planned developments in the area. It would identify the appropriate land-use zones and restrictions necessary to ensure environmentally sustainable development. In this way the SEA enables trade-offs between conservation and development endeavours to be made in an open, transparent and informed manner.

Government agencies — such as Departments of Mines, Minerals and Hydrocarbon Resources, and Planning (at the national and local level) and National Environment Agencies — should commission the SEA. The assessment should involve extensive consultation with local government, communities and interested organisations.

4.2.2 Environmental impact assessment

Environmental impact assessment (EIA) is the principal planning tool for assessing the environmental and social impacts of a specific development. Usually the proponent of the development applies to the national environment agency. The type and scale of the development determines whether it will require an EIA. Mining and petroleum developments generally require an EIA, as do major infrastructure such as roads, pipelines and powerlines. The proponent then prepares detailed terms of reference for the EIA; the agency should approve them before the study is commissioned. Usually there is a requirement for the EIA to include a significant element of public consultation, and for the results to be presented publicly. Once completed, the EIA report is sent to the national environment agency for appraisal and approval.

There are many guidelines on the procedures to be adopted for EIAs, some of which are specific to mining or oil production. Many countries have developed their own EIA guidelines for use within their legal and planning system.

Typically, EIAs are supposed to consider alternatives in sites, routes and methods of extraction. They enable the proponent to identify the best of these alternatives from environmental and social perspectives. In the case of mining and petroleum development, the site is largely determined by the presence of the resource and where it is most accessible. The EIA should facilitate choice between modes of operation, access routes, or orientation of the site (e.g. to minimise the impacts of dust fall-out).

The purpose of the EIA is to identify the main risks and propose mitigation measures to minimise them, and to optimise the beneficial impacts. It provides the basis for the Environmental Management Plan (section 4.2.3). The EIA should consider in detail the proposals for each phase, activity and location, and identify their environmental implications. In arid and semi-arid zones, the particular focus would be on dust release, scarce water resources, vulnerable desert ecosystems, and the socio-economy of local communities. If toxic or hazardous materials are being released in the process, the risks of spills and discharge will have to be considered.

The EIA should also identify indicators with which to monitor environmental performance. These are set against the baseline of existing conditions, and incorporate the range of acceptability of change. Although there are many international and national standards for emissions and discharges to air, soil and water, most of them have been developed in an urban context. Appropriate emission standards should be based on the prevailing conditions in arid and semi-arid zones.

4.2.3 Environmental management plans

The Environmental Management Plan (EMP) identifies the principal environmental hazards and the ways in which the company proposes to address them. The plan should be ongoing, with targets set for different activities, to facilitate the monitoring of progress. Within arid and semi-arid zones the major emphasis should be water conservation, dust management, topsoil storage and rehabilitation/restoration, but it should also include a detailed waste management plan and an emergency contingency plan (EMP). Environmental performance is evaluated against this plan.

The Environmental Management System (EMS) provides an organisational framework for the EMP. It details areas of responsibility, staff resources and training requirements, documentation, reporting and communication. The EMS will outline, for instance, what records and documents may be required, who will keep them and who will use them and how they should be distributed (Box 4).

Box 4. Key components of environmental planning and management

The most important international standards for environmental planning and management are contained within the ISO 14000 series, which are generally applicable to any business activity. As set out in these standards, the development of an environmental management system will be based upon the following:

Information: All mining or oil operations aiming at environmental compliance will need to describe the baseline environmental conditions. An environmental survey, including assessments of the air, soils and water resources and the key features of the ecosystems surrounding the site and outlining their importance and sensitivity, should be carried out. This information provides the basis for assessing future change and requirements for site rehabilitation. The survey should also highlight the different activities of the operation and the environmental risks and hazards associated with each of them.

Involvement of local communities: Involving local communities and key stakeholders is essential for sustainable environmental management. Social studies, consultation and active participation are needed before, during and after the development activities take place. Agreements will be required with the communities on the timing of activities and the expected impacts.

Environmental management planning: Based on the baseline survey and social studies an environmental management plan should be developed. The management plan would outline the measures required to minimise environmental and social impacts and their implementation. Such a plan is not a blueprint, however; it needs to be flexible and adaptive as new information becomes available. An environmental monitoring programme will be required to provide this information.

Communications: An environmental management plan should also identify how information about environmental conditions of the site should be communicated, both within the company and to the outside. A liaison group within the local communities should be set up for this.

Training for environmental management: Environmental management is a new discipline. Training will be needed for both site managers and operational staff to make them aware of and skilled in their environmental responsibilities. Large sites should have their own environmental manager. Training may also be offered to people from local communities.

Contingency plan

As part of the Environmental Management Plan, a Contingency Plan should be prepared to deal with emergencies such as explosions, fires, flash-floods, landslips, major spills, seepages and collapse of tailings dam walls. A risk assessment should be carried out to identify the potential causes of emergencies and the likely consequences. Based on this assessment the necessary clean-up equipment and chemicals can be procured, so that they are on hand when needed, and staff training and practices can be carried out. Contingency plans should include the following:

- identification of risks and objectives;
- identification of threats to sensitive areas both inside and outside the site, including stores and equipment, worker accommodation, local communities, local habitats and ecosystems and water sources;
- a response strategy for each significant risk;
- a strategy for communications and reporting;
- determination of resource requirements;
- determination of action plans; and
- definition of training and exercise requirements.

It is important that local communities be aware of the emergencies that might occur at the site. Awareness creates preparedness among the local population, and involves them in emergency responses and in protecting themselves and their property more effectively. To this end, UNEP has developed the Awareness and Preparedness for Emergencies at the Local Level programme (APELL).

Emergency response training and practices are essential. Government agencies should ensure that the companies develop such emergency-response strategies and provide appropriate training for their staff. They should make clear which agencies should be notified in the event of an emergency.

Wetland restoration, copper mine, Chile.
Photo, Anglo American/Phil Tanner

Rehabilitation and restoration plans

If permanent closure is decided upon, the operator should provide further details about the outlined closure and site restoration. It is essential to consult with local authorities and communities before detailed closure plans are drawn up.

Restoration of drill site after exploration, Namibia.
Photo, Anglo American

A rehabilitation plan ideally includes returning the land to its original state. Restoration goals would in most cases be related to pre-mining land-uses, such as wildlife habitat, livestock grazing, and rain-fed or irrigated agriculture.

Rehabilitation and restoration should not be considered only at the end of the operations. Many mines progressively extract raw materials and return the overburden to those areas where mining activity has ceased. Concurrent rehabilitation and restoration during active mining allows worked-out areas to be revegetated and is ecologically and economically more viable than leaving rehabilitation and restoration activities to the end. Rehabilitation and restoration should therefore be an integral part of the EMP.

It is essential that some kind of financial provision be made for rehabilitation and restoration. A sinking fund or trust fund, to which the company contributes regularly from the beginning of its operations, is one option (Box 5). The fund should be geared to the expected restoration costs of the site, and these estimates should be revised as needed during the life of the operation. The fund should be managed by a board, which needs to include representation from both the local government and communities.

Box 5. Sinking funds and trust funds

Financing closure and restoration is a key issue for companies, licensing and planning authorities and the local communities. Adequate financing will help ensure safe closure, accurate site restoration and future land uses.

Sinking or trust funds, both for site rehabilitation and restoration and for future development activities, allow some of the benefits of the development to be passed on to future generations. It is essential that these funds be built up during the operational life of the mine or oil field, rather than waiting until the end. Administration and control of the trust fund should include representatives of the communities, and mechanisms should be put in place to ensure wise use of the money.

Many mineral and petroleum extraction licences now require a company to take out closure insurance, so that in the event of unforeseen technical, economic, or political circumstances, which force early closure of the development, adequate funds are available for rehabilitation and restoration. Insurance premiums are taken out in conjunction with the sinking fund, and they decline as the fund increases. The terms and conditions of such funds and insurance schemes will depend on national laws and regulations. Establishing such schemes will require professional legal and financial assistance.

4.2.4 Monitoring, environmental auditing and reporting

Adequate information on baseline environmental conditions is important for comparing changes and trends as a result of extractive industries development activities. This includes not only the physical and chemical conditions (air, soil and water) but also ecological and socio-economic factors.

Biological indicators are often far more sensitive to cumulative impacts of low-level toxic emissions. The choice of such biological indicators in arid and semi-arid zones may be very specific to the site (Tables 6 and 7).

Monitoring and interpreting ecological changes in arid and semi-arid zones may be challenging due to the climate, e.g. after rainstorms and during persistent drought. Monitoring environmental conditions in such zones may be physically arduous for staff, and even remotely controlled instruments are liable to break down under the extreme conditions.

The results of monitoring environmental conditions carried out as part of an Environmental Management Plan (EMP) should be made available in a regular report to the permitting authorities, who may carry out their own site monitoring and environmental audits. The company may wish to commission an independent environmental audit for its annual report to shareholders, government authorities and local communities.

For a major mining or petroleum development, the responsible government agency may consider setting up an inter-agency commission or steering committee. This body should have representatives from the government agencies concerned, local government and adjacent communities. The environmental managers of the company and any commissioned monitoring agencies should report to this committee. The committee should publish an annual report that synthesises monitoring activities carried out during the year, and indicates trends. The report should indicate whether changes in the EMP and monitoring programme are required.

Table 6. Factors in assessing desertification

Type	Subtype	Factor
Physical	Climate	a. rainfall b. temperature c. wind speed, direction and frequency d. rain erosion potential (calculated) e. sunlight duration f. potential evapotranspiration (PET; calculated) g. sandstorms/dust storms h. vortices
	Soils	a. surface status (rockiness) b. texture c. fertility (organic matter) d. structure e. permeability f. erosion potential (calculated) g. alkalinization/salinization h. soil unit map
	Topography	a. slope
Biological	Vegetation	a. canopy cover of herbaceous and woody plants (%) b. above-ground biomass production (standing crops) of herbaceous/woody cover (kg/ha/yr) c. plant composition and desirable or key species d. potential herbaceous production (calculated) e. vegetation unit map
	Animals	a. animal population estimates and distribution b. herd composition c. herbaceous consumption (calculated)
Socio-economic	Land and water use	a. land use b. fuelwood consumption c. water availability and requirements
	Settlement patterns	a. settlements b. infrastructure
	Human biological parameters	a. population structure and growth rate b. measures of nutritional status c. feeding habits
	Social process parameters	a. conflicts b. migration c. transhumance d. environmental perception

Table 7. Indicators in assessing desertification

Type	Subtype	Indicator	Level of application	
Physical	Climate	a. aridity index	L	N
		b. rainfall variability	L	N
		c. wind deposition and deflection areas	L	
		d. wind erosion potential (calculated)	L	N
	Soil	a. crusting and compaction	L	
		b. soil salinization/alkalinization	L	
		c. water erosion areas	L	
		d. water erosion potential (calculated)	L	N
Biological	Vegetation	a. vegetation degradation (herbaceous and woody; calculated)	L	N
		b. range carrying capacity (calculated)	L	N
		c. desirable and undesirable plant species	L	
Socio-economic	Human factors	a. human settlements	L	N
		b. land use	L	N
		c. fuelwood consumption (calculated)	L	N
		d. nutritional status	L	N
		e. migration	L	N
		f. environmental perception	L	

L = local; N = national

Source: Krugmann, H. 1996. Toward Improved Indicators to Measure Desertification and Monitor and Implementation of the Desertification Convention. In H. Hambly and T. Onweng Angura (eds.) *Grassroots Indicators for Desertification: Experience and Perspectives from Eastern and Southern Africa*. IDRC.

Chapter Five

Policy guidance

This chapter summarises the key principles that will help government officials responsible for licensing, planning and monitoring of extractive industries development activities, along with environmental NGOs, and executives of extractive industries, ensure that exploration and exploitation activities in arid and semi-arid zones have minimal impact on the environment. It will also help ensure that essential ecosystem goods and services are conserved to sustain long-term development. These principles are presented in three sections: 5.1) Planning and management of natural resources; 5.2) Policies, laws, and institutions; and 5.3) Monitoring.

In each section the principles are organized in relation to the institutions that would normally have responsibility for undertaking the suggested actions.

5.1 Planning and management of natural resources

To ameliorate the impact of extractive industries in arid and semi-arid zones and negative influences on societies, which can contribute to land degradation and desertification the following guidance is provided:

Permitting and monitoring agencies should:

- ensure that exploration and production companies are aware of the ecological and social dynamics in the vicinity of sites to be developed before beginning development of the site;
- assess and approve the findings from baseline studies, Environmental Impact Assessments and Environmental Management Plans.

Extractive companies, in relation to environmental considerations, should in all stages of their activities:

- identify existing sources and patterns of water use and design supply systems, to optimise ground water recharge and minimise surface disturbance, and use and disposal of waste waters to protect these sources;
- minimise the risks of pollution and contamination of water sources with due regard to natural levels of water quality;
- avoid developments which threaten to lower the water table and dry up or pollute wetlands;
- study seasonal variations pertaining to air quality to assess the impact resulting from mining and oil/gas operations;

- assess the overall visual impact of the mining or oil production site and its associated infrastructure;
- take precautions to store and reuse topsoil removed during operations;
- document the range and diversity of flora in the vicinity of sites to be developed;
- take precautions to conserve vegetation by limiting its removal and by revegetating using native plants as soon as possible;
- not start fires and use appropriate protection such as firebreaks;
- assess demand for firewood in the vicinity of sites and where needed provide sufficient firewood to ensure that demand does not lead to deforestation;
- ensure that site development, including infrastructure such as pipelines and roads, do not disrupt diurnal or seasonal migrations of species;
- control hunting, poaching and bushmeat consumption by their workers;
- protect genetic resources and ecosystems in the vicinity of their developments;
- pursue activities in protected areas designated as IUCN Categories V and VI only if: a) an environmental impact assessment has been prepared and approved by the relevant government department; b) strict operating guidelines are in place to monitor and adapt activities to avoid permanent impacts on the habitat in the protected area; and c) provide assurances that after the site is closed, the company will cover the cost of any necessary ecological restoration;
- ensure that minimal degradation of land occurs as a result of contamination, loss of soil structure, or changes in hydrological balance, e.g. decrease in water availability for irrigation, or increase in the water table causing salinisation.

Extractive companies, in relation to socio-cultural conditions, should:

- respect existing communities and recognise ethnic and cultural identities and rights in planning developments associated with mining and oil development, using sound participatory techniques;
- respect traditional land use, natural resource utilisation, and tenurial and/or usufruct rights and, in consultation with government and private planning agencies, take into account such uses and rights in plans for economic development and compensation agreements;
- provide scholars and researchers access to study archaeological sites and underwrite the costs to conserve such sites to promote greater understanding of ancient cultures and history in the area where the development;
- respect traditional practices and movements of nomadic peoples and pastoralists;
- be equitable and fair in employing local people in work forces; use local skilled workers and where possible develop local capacities by providing appropriate training;

- ensure that company-run stores sell merchandise at prices that are within local peoples' ability to pay;
- identify health-related risks for workers and local populations and take steps to prevent or minimise those risks including development of contingency plans to handle health risks;
- minimize operational hazards on sites and inform workers of health/accident risks.
- provide opportunities for education, health care and employment for local people while ensuring that equitable access to these opportunities exists;
- develop, in consultation with local people, the plans and the means (e.g., trust funds), to sustain development of local peoples' quality of life once exploitation of the resource has ceased.

5.2 Policies, laws and institutions

To ensure that extractive industries' development activities are compatible with needs to maintain national environmental "capital" and long-term sustainable use of land, it is essential that governments have in place relevant policies, laws and an effective institutional framework, which is guided by the following principles:

Government licensing and permitting agencies should:

- liaise with planning and environmental agencies to ensure that extractive industry development activities are compatible with environmental protection and sustainable land use;
- ensure that a prerequisite for obtaining a permit or licence includes early closure insurance and the establishment of trust funds to cover restoration costs;
- encourage, where appropriate, artisan miners and other local people to establish small companies and co-operatives to foster local economic development;
- require extractive industries to follow a "codes of practice" programme for environmental protection during exploration and surveying activities;
- provide clear explanations of institutional responsibilities at each step in the permitting and monitoring process;
- liaise with those government departments that share responsibility for different facets of environmental and natural resource management and conservation as well as those responsible for social needs;
- ensure that an independent strategic environmental assessment is commissioned and carried out in collaboration with planning and environmental/natural resource management agencies before the decision is made on the development of an extractive industry;

- ensure that the company applying for a permit has undertaken an environmental impact assessment, including a baseline survey of environmental and social conditions and measures to mitigate any impacts, that such impact assessment has undergone a due process of public consultation and review, and that input from such consultation has been reviewed and integrated in the final environmental impact assessment, and has been approved by the responsible agency/department before granting a licence or permit;
- ensure that environmental management plans, which take into account risks and outline contingency plans, have been developed and approved before licences or permits are granted;
- ensure that the interests of local communities are protected, that corporate responsibilities with respect to these communities are clear, that the communities and other relevant stakeholders are aware of those responsibilities and rights and, where appropriate, facilitate negotiations between the companies and communities;
- ensure that communities that would be affected by proposed exploration and extraction projects are aware of the proposed activities and have the opportunity to comment on documents;
- carry out regular audits of the licensed or permitted concession activities to ensure that environmental and social mitigation measures are being implemented and that companies are adhering to agreed codes of practice;
- regularly review implementation of environmental management plans and include changes where necessary;
- provide technical support, advice and training to artisanal and small- and medium-sized mining companies to increase awareness of environment, management and social issues and the capacity to address them.

Planning, environment and natural resource management agencies should:

- ensure that land-use and planning legislation and policies are compatible with legislation and policies for mineral and petroleum development, and that the latter integrate conservation needs;
- review and comment on proposals for exploration and/or surveys for oil, gas or minerals within their country;
- collaborate with the permitting agencies in carrying out a strategic environmental assessment of large-scale extractive developments;
- ensure applicants for extractive licences or permits have completed and met government land-use planning requirements;

- ensure that companies applying for extractive licences or permits have consulted local authorities and communities and, where necessary, adequate compensation packages have been agreed;
- ensure that closure and rehabilitation/restoration plans are discussed with local authorities and communities and that all parties accept the final closure plans;
- ensure that the legal requirements for environmental impact assessments are fulfilled;
- comment on and approve terms of reference for environmental impact assessments, and review, comment and approve the impact assessments that have been carried out;
- comment on and approve the environmental management plans;
- consider application of appropriate air quality standards, taking into account prevailing natural conditions of dust in arid and semi-arid zones;
- ensure that water resources are protected and used sustainably under the proposed development, considering water extraction and discharge standards, and bearing in mind prevailing natural ground water availability and quality in arid and semi-arid zones;
- strive to avoid water resource conflicts between the company and local peoples' needs for water, including for their livestock and agriculture;
- ensure that natural resources under the responsibility of different agencies (forests, grasslands, agriculture, wetlands etc.) are adequately protected under proposed developments;
- ensure that extractive industry developments are not permitted in the strictest categories of protected areas (IUCN Categories I–IV), and that appropriate protection measures are put in place where developments are adjacent to protected areas, or are in restricted locations in less strictly protected areas.

5.3 Monitoring

Monitoring extractive industries performance in relation to agreed procedures is crucial to ensure that licence- or permit-holders are accountable for their actions. The following guidance is provided for government, industry, and local stakeholders, each of which is seen as important partners in fulfilling monitoring requirements;

Government licensing and monitoring agencies should:

- establish an inter-agency commission or steering group, with representation from all relevant agencies, the licence/permit holder and other stakeholders to oversee licensed or permitted activities;

- define indicators to monitor impacts on the environment, social structure and health and safety at different phases of the project, e.g., survey and exploration, appraisal, production and operation, closure and rehabilitation/restoration;
- where baseline information is inadequate, consider further studies to complement existing information;
- ensure that regular monitoring of environmental and social conditions is carried out as programmed;
- ensure that all the monitoring reports are pulled together and discussed;
- ensure that an annual report summarizing the results of the monitoring activities is made available to the public.

Extractive industries should:

- prepare and implement corporate environmental and social policies;
- establish a unit that is responsible for management of environmental and social issues, with authority to implement environmental management plans on site;
- ensure that contractors, sub-contractors and suppliers are aware of corporate environmental and social policies and that compliance with these is a condition of contract;
- inform and consult with local government agencies and communities in applying for licences or permits and in implementing approved activities, explaining the scope of the different activities at each stage and the disturbance that may be involved;
- in carrying out required environmental impact assessments, take extra care to work with local communities and officials, where activities will be intrusive or prolonged or where the area has known sensitivities;
- prepare an environmental management plan before beginning any activities, which addresses: topsoil conservation and reuse; dust reduction; water conservation and reuse; waste management; conservation of biodiversity; protected areas; relations with local communities and indigenous peoples; emergency risk assessment and contingency planning; and decommissioning, closure and site rehabilitation/restoration;
- respect local water rights and try to accommodate existing water users, such as local communities, livestock and agriculture (if water is brought in from outside, a strict water conservation strategy should be applied);
- prepare contingency plans designed to respond to changing conditions;
- in view of the linkage between greenhouse gas emissions, climate change and desertification, estimate potential greenhouse gas emissions from their operations and develop mechanisms for emission reduction and/or compensation;

- ensure that land ownership and rights of access, and land use by nomadic, semi-nomadic and traditional sedentary communities are respected and, where necessary, provide adequate and equitable compensation packages to local communities and/or landowners for damages and inconvenience as a result of extractive operations.

Environment and development NGOs should:

- collate and disseminate environmental and social information to raise awareness on particular issues;
- contribute to and support stakeholder committees, steering groups etc.;
- contribute to environmental research and studies of particular issues of mining and petroleum production in arid and semi-arid zones;
- facilitate local communities' capacity to negotiate with the extractive companies.

Communities (both sedentary and mobile), community-based organisations and other local stakeholders should:

- ensure that community representatives serve on stakeholder committees, steering groups and monitoring groups;
- get involved in health and safety issues and emergency contingency plans related to the exploration and extraction of oil, gas, and minerals in areas adjacent to the communities;
- advocate for rehabilitation/restoration of sites after closure to ensure that they are safe and capable of sustaining needed ecosystem goods and services.

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Acronyms

AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
CBO	Community Based Organisation
DAC	Development Assistance Committee
DRI	Desert Research Institute
E&P Forum	Oil Industry International Exploration and Production Forum
EBI	Energy and Biodiversity Initiative
EIA	Environmental Impact Assessment
EIS	Environmental Impact Strategy
EMP	Environmental Management Plan
EMS	Environmental Management System
FAO	Food and Agriculture Organisation of the United Nations
GEF	Global Environmental Facility
ICME	International Council on Metals and the Environment
ICMM	International Council on Mining and Metals
IIED	International Institute for Environment and Development
IPIECA	International Petroleum Industry Conservation Association
IUCN	International Union for the Conservation of Nature and Natural Resources – The World Conservation Union
MMSD	Mining, Minerals and Sustainable Development
NGO	Non-Governmental Organisation
ODI	Overseas Development Institute
OECD	Organisation for Economic Cooperation and Development
OGP	International Association of Oil and Gas Producers
RIOD	Réseau International d'ONG sur la Désertification
SEA	Strategic Environmental Assessment
UNCCD	United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNGA	United Nations General Assembly

UNSO	United Nations Office to Combat Desertification and Drought
WBCSD	World Business Council for Sustainable Development
WCMC	World Conservation Monitoring Centre
WWF	World Wide Fund for Nature

Glossary

Arid	Ratio of precipitation to potential evapotranspiration 0.05-0.20°; rainfall 50-200 mm in winter, 100-300 mm in summer; sparse vegetation: woody shrubs, succulents, grasses; grazing and irrigation, but no rain-fed cropping
Alluvial Fan	Formed when streams run off mountains in deep gorges to plains below and deposit rock material
Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs for that unit to have economic value as a source of water in that region
Badlands	Areas of little or no economic value, generally devoid of vegetation, with rugged terrain and poor access; often with fluvial erosion features
Benches	Natural or man-made step-like terraces; benches in an open-pit mine are formed when successive layers are removed; benches are also safety features that serve to catch any loose rock that starts to roll down the side of an open pit
Cuttings	The fragments of rock dislodged by the drilling bit and brought to the surface in the drilling mud
Degraded	Reduction or loss of biological or economic productivity of the land
Desert pavement	Topmost layer of angular stones covering desert surfaces; the dust falling on these stones is washed beneath the surface
Desert varnish	A thin dark surface patina formed by a combination of leaching out of iron and manganese from underlying rocks and dust, and the action of lichens and bacteria
Desertification	"Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" – as agreed at the 1992 Earth Summit in Rio de Janeiro and adopted by the UN Convention to Combat Desertification (UNCCD)
Dewatering	Lowering of the water table
Drilling mud	Specialised fluid made up of a mixture of clay, water and chemicals, which is pumped down a well during drilling operations to lubricate the system, remove cuttings and control pressure
Drylands	Areas with low annual precipitation, prolonged periods of heat, low relative humidity and high rates of evaporation; includes zones classified as hyper-arid, arid, semi-arid and dry sub-humid; these aridity zones are delineated based on an aridity index, which is determined by the ratio of precipitation to potential evapotranspiration
Drought	The naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems
Dry sub-humid	Ratio of precipitation to potential evapotranspiration 0.50–0.65 degrees; >500 mm in winter, 600–1200 mm in summer; grasslands, savannahs and woodlands; rainfed cropping and grazing
Ecosystem restoration	Recovery of the structure, function and processes of the original ecosystem

Erosion	The gradual disintegration of the soil surface by chemical or physical weathering
Evapotranspiration	The sum of water loss from both plants and soil measured over a specific area
Gangue	Rock surrounding a mineral or precious gem in its natural state
Flaring	Controlled burning of surplus combustible gases in the atmosphere
Flotation	A form of concentration of certain minerals from gangue based on their different surface reaction to chemical flocculants; a reagent is used to adhere to the target mineral, which then rises to the top of the flotation cell with injected air, where it can be collected.
Hyper-Arid	Ratio of precipitation to potential evapotranspiration <0.05 degrees; rainfall <50mm in winter, <100mm in summer; little or no vegetation; true climatic deserts, e.g. Sahara, Atacama (UNEP 1992, *World Atlas of Desertification*)
Leaching	Slow passage of a solvent through a layer of porous or crushed material in order to extract valuable components; for example, gold can be extracted by heap leaching a porous ore or pulverised tailings
Lixiviant	Chemical used for in-situ leaching of minerals such as uranium and copper. It may be acidic, basic or neutral and may contain oxidants
Longwall mining	Underground mining where entries and crosscuts are created around a large block which is eventually mined out resulting in subsidence of the ground surface
Metals	A material with a high reflectivity and conductivity that can usually be deformed plastically; also refers to metallic elements when these are combined with other elements to form non-metallic compounds such as salts and oxides
Mill/concentrator Processing plant	Surface plant facilities for ore treatment that allow for the recovery and removal of metals or the concentration of valuable minerals for smelting and refining
Mineral	A substance produced by the processes of inorganic nature; often extended to certain substances of organic origin got by mining such as coal or amber
Open pit	A surface mine, such as a quarry, open to daylight; also referred to as open-cut or opencast mine
Overburden	The rock and soil cleared away before mining
Placer	An alluvial deposit of sand and gravel containing valuable metals such as gold, tin, etc.
Placer mining	Mining sand and gravel deposits for their mineral content
Playas	Depression where rainwater can accumulate (also dry lake or pan). Usually flat with no vegetation; water can persist for several weeks after rainfall
Produced water	Water from the natural oil reservoir which is separated from the oil and gas in the production facility
Production	The phase of the petroleum industry that deals with bringing the well fluids to the surface and separating them, and with storing, gauging and otherwise preparing the product for the pipeline
Raise/Chute	Steeply inclined rectangular or cylindrical opening used for ventilation or for conveying ore, miners or equipment; the slope is generally 45 degrees, but varies up to 90 degrees

Rangelands	Land that has vegetation suitable for grazing livestock, but that is too arid for crop farming
Refining	Purifying matter or impure metal; undertaken to obtain a pure metal or mixture with specific properties
Rehabilitation	Re-establishment of part of the productivity, structure, function and processes of the original ecosystem
Runoff	The portion of precipitation that runs off the surface as opposed to soaking in
Salinization	The accumulation of salt in soil and water to a level that causes degradation and prevents the growth of plants; it may be caused by irrigation as salts brought in with the water remain in the soil as the water evaporates
Savanna	A type of grassland usually dotted with trees supported by a wet season and dry season and frequent natural fires, typical of subtropical regions, particularly in Africa
Semi-Arid	Ratio of precipitation to potential evapotranspiration 0.20-0.50 degrees; rainfall 200–500 mm in winter, 300–600 mm in summer; grasslands, shrubs and savannahs supporting grazing and some rainfed cropping
Shot hole	A borehole in which an explosive is placed for blasting in use as the energy source for seismic activity
Subsoil	The soil beneath the topsoil; compacted, with little or no organic material
Tailings	Finely ground rock waste: material rejected from a mill when the recoverable minerals have been extracted
Topsoil	The surface layer of soil, which is rich in humus and other organic material, living and dead; enerally has a loose, crumbly structure
Transhumance	Seasonal migration of livestock to suitable grazing grounds
Transpiration	The loss of water vapour from land plants
Vibroseis	A seismic survey technique which uses large vehicles fitted with vibrating plates to produce shock waves

Annex 1. Mineral processing methods and emissions/wastes

Material and typical products	Typical process requirements	Process methods	Process wastes and emissions	Potential environmental issues
Aluminium				
From bauxite; numerous grades of aluminas and their fused products based on a combination of chemical purity e.g. aluminium metal, aluminium trihydrate (filler) and alum	Refining or smelting, usually off-site in an area convenient for bulk trans-port with natural cheap power generation, e.g. hydro-electric power	Crushing, digestion, hot NaOH, clarification, precipitation, calcination and smelting	Waste initially 800°C, caustic soda, iron and altered clays, SO_2 and CN	Increased energy demand in process area, bulk transport issues, tailings dams
Gold				
Primary gold found in quartz vein, secondary gold classed as placer deposits; gold of varying purity used in a variety of industries (by-product of copper mining)	Deep mine, large-scale surface extraction, hydraulic mining of surface deposits, working surface dumps with mercury and dredging placer deposits from a boom-equipped barge	Cyanide leaching thiourea, thiosulphate, bromine, chlorine and iodine possible alternatives to cyanide; mercury combines with gold, which is heated, mercury evaporates to leave gold	Free cyanide, metal cyanide complexes, evaporated mercury	Land degradation, pollution of atmosphere, soil, silt and water by harmful chemicals
Silver				
Found in sulphide minerals, by-product of copper, zinc and lead mining	Surface, underground and experimental mining	Cyanidation, elution, electro-winning/zinc preparation, milling, base metal flotation and smelting	Mine water, overburden/waste rock, spent process solutions, tailings and spent ore	Contamination of soil, surface and ground water
Lead/Zinc				
Typically mined together; found in a variety of minerals, including sulfides, oxides and silicates	Near surface opencast, large tonnage, rapid, cheap; Stoping of vein/orebody deposits	Crushed below surface or within opencast; milling, flotation, sintering and smelting	Mine water, overburden, waste rock, tailings and slag; possible contamination from associated heavy metals	Opencast, large scale destruction of land, noise, dust etc., acid mine drainage
Iron				
Occurs as hematite, goethite and magnetite; used in a variety of industries	Large-scale opencast mining; some underground workings	Milling, magnetic separation, gravity separation, flotation, agglomeration and blast furnace	Mine water, overburden/waste rock, tailings and slag	Development of large opencast site, bulk transportation; mine water drainage

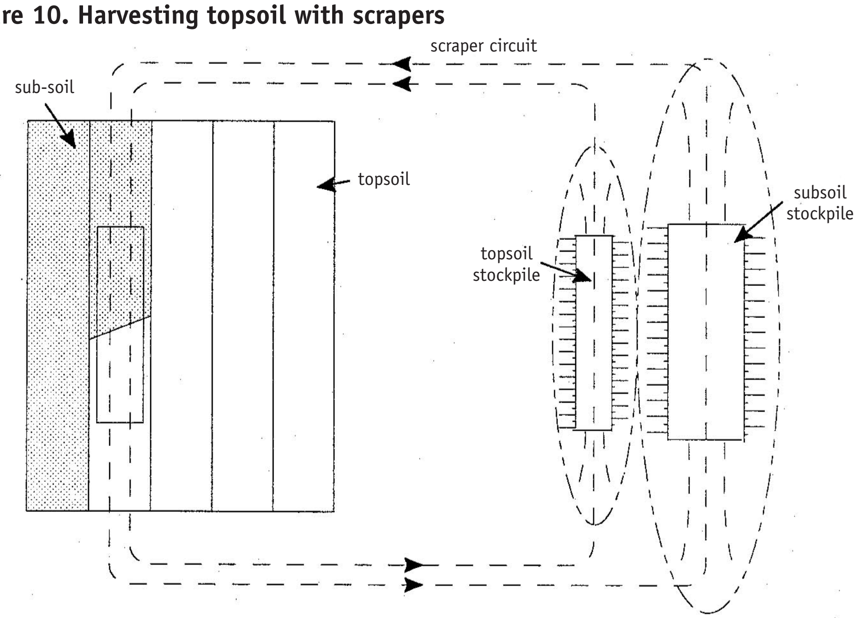
Material and typical products	Typical process requirements	Process methods	Process wastes and emissions	Potential environmental issues
Copper				
Occurs in low percentages as sulphides, oxides and carbonates in other minerals; used in alloys, paint and electro-plating base metal	Opencast mining on a huge scale	Milling, flotation, smelting, acid leaching; SX/EW recovery and iron precipitation/ smelting	Mine water, overburden/waste rock, tailings, slag, spent ore and spent leach solutions	Development of large opencast site, bulk transport issues, noise, dust, contamination of surface soils and sediments
Sand				
Silicates are used in a variety of industries, from chemical to construction	Shallow surface stripping	Crushed, sorted, washed to remove fines, classified, dewatered, leached to remove impurities, and dried	Overburden, tailings and spent process solutions	Bulk transportation, disposal of spent process solutions and fines
Diamonds				
High pressure carbon mineral, used in jewellery, polishing and drills	Placer deposits, deep mine extraction (kimberlite pipes)	Passed over greasing tables to remove gems	Tailings dams, spoil heaps, leachate generation	Discarded spoiled tips
Salt				
	Injection of water via wells in the salt or halite deposit, salt brine is withdrawn and either evaporated or transported to a chemical processing plant rock salt mining using room and pillar techniques. underground blasting, under-cutting and drilling extraction methods	Salt solutions are dried or the brines are piped directly to a chemical plant (captive brine wells) for chlor-alkali or other chemical production rock salt mining: crushing, screening to remove fines and bagged	Generation of fines deposits	Surface subsidence due to solution cavity formation

Material and typical products	Typical process requirements	Process methods	Process wastes and emissions	Potential environmental issues
Borax				
Complex borate mineral found in playa lakes and other evaporite deposits; used in pottery and medicine; borate minerals are mined primarily for boron	Underground room and pillar mining, using a combination of conventional, continuous and shortwall mining equipment. Also extracted via solution mining and surface mining	Mined, crushed, screened and processed	Washings from tailings dams	Bulk transport issues
Coal				
Various coal grades from anthracite to bituminous; used for energy generation and chemical industries	Opencast or deep mining	Mined, sorted, washed, flotation and chemical processes to remove ash and sulphur prior to burning, crushed and graded	Extensive spoil heaps, mine water drainage, tailings dams	Subsidence resulting from deep-mining, mine water drainage and mine gases
Phosphate				
	Surface mining	Washed to remove overburden materials, flotation, dried to produce phosphate rock; wet concentrate used to produce phosphoric acids and diammonium phosphate	Clay and earth from pre-washer plant to tailings dam, sand used to fill mine cuts; phosphogypsum process waters	Bulk transportation issues, and failing tailings dams polluting surface and ground water
Uranium				
Present in most rock types, predominately igneous and sedimentary	Mining or acid leaching (sometimes undertaken in situ where deposits are permeable, e.g. sandstone)	Primary treatment at mine, crushing and acid digestion, solvent extraction, precipitation and drying, transport to processing plant; re-dissolved, thermally decomposed, smelted to form uranium metal and $MgFl_2$ slag; enrichment, calcined to produce UO_2	Spoiled tips and $MgFl_2$ slag	Degradation of land around the mine, transportation and disposal of radioactive waste

Annex 2. Topsoil harvesting techniques

- Buffer strips of vegetation should be conserved wherever possible.
- Topsoil should be re-used as quickly as possible within operational constraints.
- Consider sequential harvesting of topsoil to allow the direct placement of soil on areas to be restored from areas being cleared for exploitation. With careful planning, this technique can minimise handling costs.
- Locate stockpiles near the probable locations required for reuse. Ensure that they do not become isolated and inaccessible as a result of other operations, or where they could become polluted.
- If possible, topsoil and subsoil should not be harvested or respread if they are either very wet or very dry. A moisture content between 15 to 20 percent of water-holding capacity is generally the optimum for moving soil.
- A significant proportion of the limited arid and semi-arid topsoils can be lost during land clearance operations when surface vegetation is piled into windrows. In order to minimise the loss of valuable topsoil, bulldozers may be equipped with a root-rake to allow woody vegetation and roots to be windrowed without removing the soil.
- Where available, scrapers are the most efficient means of removing topsoil. Scraper circuits should be planned to minimise topsoil compaction (Figure 10).

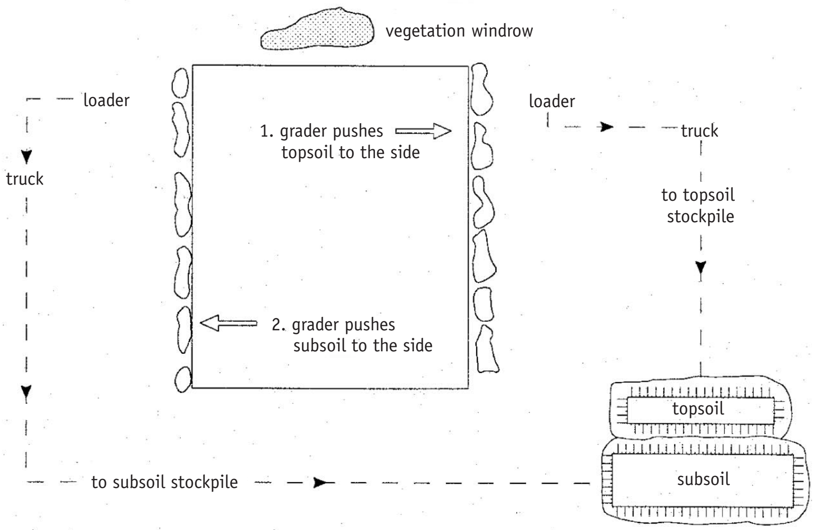
Figure 10. Harvesting topsoil with scrapers



Source: Department of Minerals and Energy, Western Australia. 1996. *Guidelines for Mining in Arid Environments.*

- Where graders, loaders and trucks are to be used, compaction from other heavy machinery can be avoided if the grader pushes topsoil to the side of the clearance area where it can be loaded into the trucks. Alternative routes can also be used to access topsoil and subsoil stockpiles (Figure 11).

Figure 11. Harvesting topsoil without scrapers



Source: Department of Minerals and Energy, Western Australia. 1996. *Guidelines for Mining in Arid Environments*.

- Topsoil and subsoil should be laid out in separate piles. In order to avoid compaction and breakdown in soil structure and biological viability, topsoil stockpiles should not be greater than one metre high. Subsoil stockpiles can be of any size. Where only a small amount of topsoil is present, it can be laid out in shallow, wave-shaped piles to maximise aeration.
- Upon completion, the topsoil stockpile should be ripped with a tine to the full depth of the stockpile to assist aeration, drainage and root penetration.
- Natural revegetation should be encouraged to maintain the viability of soil organisms and propagules, and to prevent erosion by wind and water.
- Although topsoil stockpiles can become a source of fugitive dust during windy, dry-season conditions, dust suppression water should not be sprayed on them. Even water with a very low saline level will result in salt accumulation that will greatly reduce the value of the resource for revegetation. If stockpiles are likely to remain in place for a long time, or to cause excessive dust, they can be lightly sheeted with river gravel or sown with a local indigenous grass or groundcover species.

Annex 3. Bioremediation technologies

- Bioventing, the process of aerating soils to stimulate in-situ biological activity and promote bioremediation;
- Nitrate addition, the process of adding nitrate which can act as an alternate electron acceptor under low or negligible oxygen concentrations to promote bioremediation; and
- Hydrogen peroxide addition, the process of injecting hydrogen peroxide to serve as an oxygen source to overcome anaerobic conditions and stimulate in-situ biological activity and promote bioremediation.

A well-established combination of techniques is landfarming. Oil and debris is spread over an area of land, and the oil is biodegraded by micro-organisms. Once the oil has degraded, the soil may be capable of supporting a wide variety of plants, including trees and grasses.

In order for the oil to biodegrade, it must first be mixed with a moist substrate. It may take as long as three years before the bulk of the oil is broken down, although this period can often be shortened by aeration and the application of fertilisers. Because of landfarming's requirement for water, its use may be limited under arid conditions.

Landfarming requires a large amount of land, and is only likely to be applicable to relatively small spills. Ideally the land selected should be impermeable, of low value, and located well away from drinking water supplies. For surface contamination, maintaining an adequate supply of oxygen is accomplished by tilling. Tilling depth is limited to about 40 cm. If the contamination zone is deeper, other types of technologies have to be used, including bioventing, composting and use of biopiles. All of these require aeration through an external supply of forced air.

Biodegradation of heavily weathered soils that are contaminated by petroleum often proceeds very slowly. This is due to problems with mass transfer of oxygen, water and other nutrients. Soil structure and the amount of petroleum and petroleum waste can further inhibit the transfer of essential nutrients to the indigenous microbial communities capable of degrading these pollutants. In such cases, ex-situ bioremediation methods such as biopiling may be more applicable. In this process, the sludge-contaminated soils are excavated and placed on an impermeable base to form a soil pile. The pile is constructed so as to allow aerobic bioremediation by aeration via perforated piping connected to an air blower, vacuum pump or barometric pump. Often biopiles are constructed with a leachate collection system for moisture addition. Nutrients can be added directly to the leachate for uniform distribution.

Annex 4. Steps in preparing a waste management plan

Step 1: Management approval — and support for the plan should be obtained. Management should be aware of the timing and scope of the plan. The goal of the plan should be established, with measurable objectives for each goal.

Step 2: Area definition — a description of the geographical area and operational activities.

Step 3: Waste identification — Operations personnel should identify all the waste generated within the area defined for each activity. A brief description should be prepared for each waste (sources, constituents, water content, oil content, volume and stability).

Step 4: Regulatory analysis — International, regional and national laws and regulations should be reviewed to determine appropriate management practices. Cases where regulations do not adequately define management requirements should also be identified.

Step 5: Waste categorisation — The physical, chemical and toxicological properties of each waste should be identified via Material Safety Data Sheets (MSDS), manufacturers information, process knowledge, historic information and lab analyses. Wastes can be grouped according to their health and environmental hazards.

Step 6: Evaluation of waste management and disposal options — Waste management options for each waste should be compiled and these options should be reviewed by appropriate operations personnel and management. Evaluation should include environmental considerations, location, engineering limitations, regulatory restrictions, operating feasibility, economics and potential long-term liability.

Step 7: Waste minimisation — Waste volume, toxicity reduction, recycling and reclaiming should be evaluated. The waste management plan should be revised to reflect any minimisation practices implemented.

Step 8: Selection of preferred waste management practices — The best practice for the specific operation and location should be selected. Life-cycle analysis, including use, storage, treatment, transport and disposal, should be considered.

Step 9: Implementation of the waste management plan — Waste management and disposal options for each waste should be compiled into one comprehensive waste management plan.

Step 10: Plan review and update — Effective waste management is an ongoing process. The plan should be reviewed whenever new management practices or options are identified. A procedure for review and update should be established and practices modified to reflect changing technologies, needs or regulations.

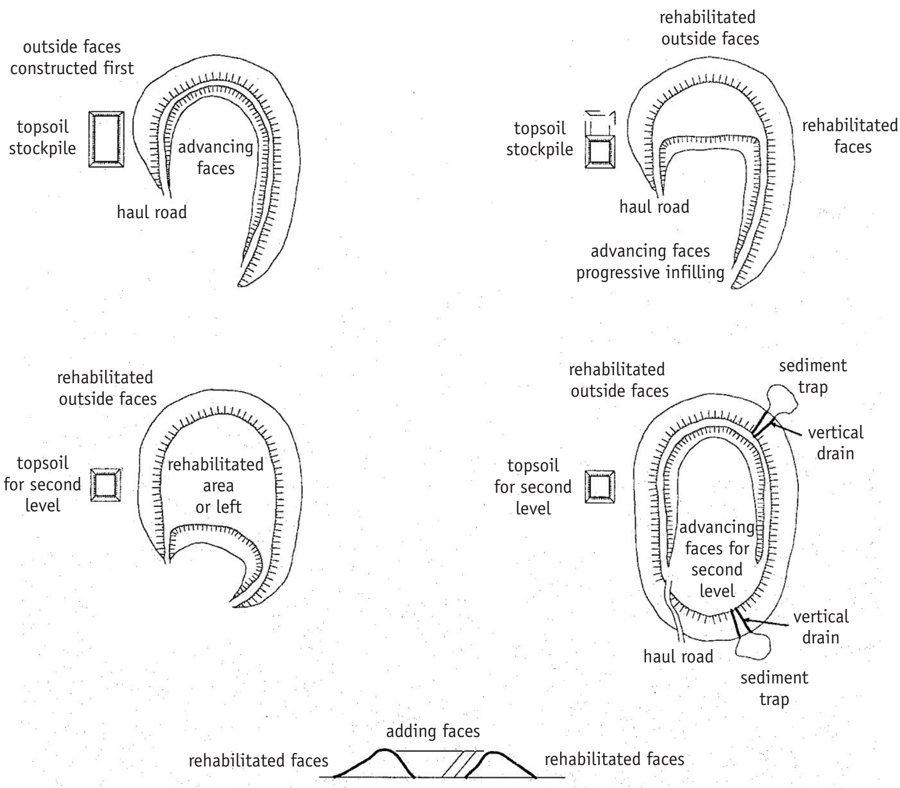
Source: E&P Forum. 1993. *Waste Management Guidelines.*

Annex 5. Waste dump construction

Three key environmental issues relate to waste dump construction: control of erosion; contaminant containment; and landscape and visual aspects. The first step in constructing a waste dump is to determine the approximate volume of material to be disposed of and the land area available for disposal. This will determine the final shape and size of the dump. In arid and semi-arid areas, erosion control and drainage is essential to prevent damage, soil degradation and release of contaminants during rainfall events, particularly where there is potential for Acid Rock Drainage (ARD), or the release of metals and other pollutants (Figure 12).

It is generally more cost-effective to construct the final landform as the waste is dumped, rather than having to handle large quantities of material twice and risk running out of space. A proven technique is to construct as waste is dumped.

Figure 12. Dump construction for progressive restoration



Source: Department of Minerals and Energy, Western Australia. 1996. *Guidelines for Mining in Arid Environments.*

- Construct the outward-facing batters first by initially dumping around one to two thirds of the boundary, which leaves room for expansion if required.
- In order to control drainage during rainfall, the berms should be sloped back into the dump with a small bund constructed along the outer edge to reduce overflow.
- The drop-down drains must be excavated from the waste rock dumps to ensure that they lie below the dump slope after placement of rock. Wing banks should be constructed to direct runoff into the drain. To prevent erosion of the drain itself, the waterway should be lined with rock, firmly secured meshing, old conveyor belting, half-round pipe or concrete formed chutes.
- Once the outside face is complete restoration should start immediately. This helps to reduce topsoil storage time. Progressive infilling can continue along the inside faces of the berm. Once the dump has been completely infilled, there may be scope to start a second level.

Rock armouring: Where erosive resistant rock is available it can be used to shield highly erodible or chemically hostile parts of the waste dump. Where rock armouring is to be used the outward facing slopes can generally be more steeply graded but must not exceed 30 degrees or less, according to the geotechnical characteristics of the waste material.

Contour ripping: In arid environments, the soil structure must resist compaction (particularly in the root zone), enhance filtration and leaching of soils and be capable of harvesting water from rainfall and runoff. For most large-scale mine landforms, contour ripping is recommended such that:

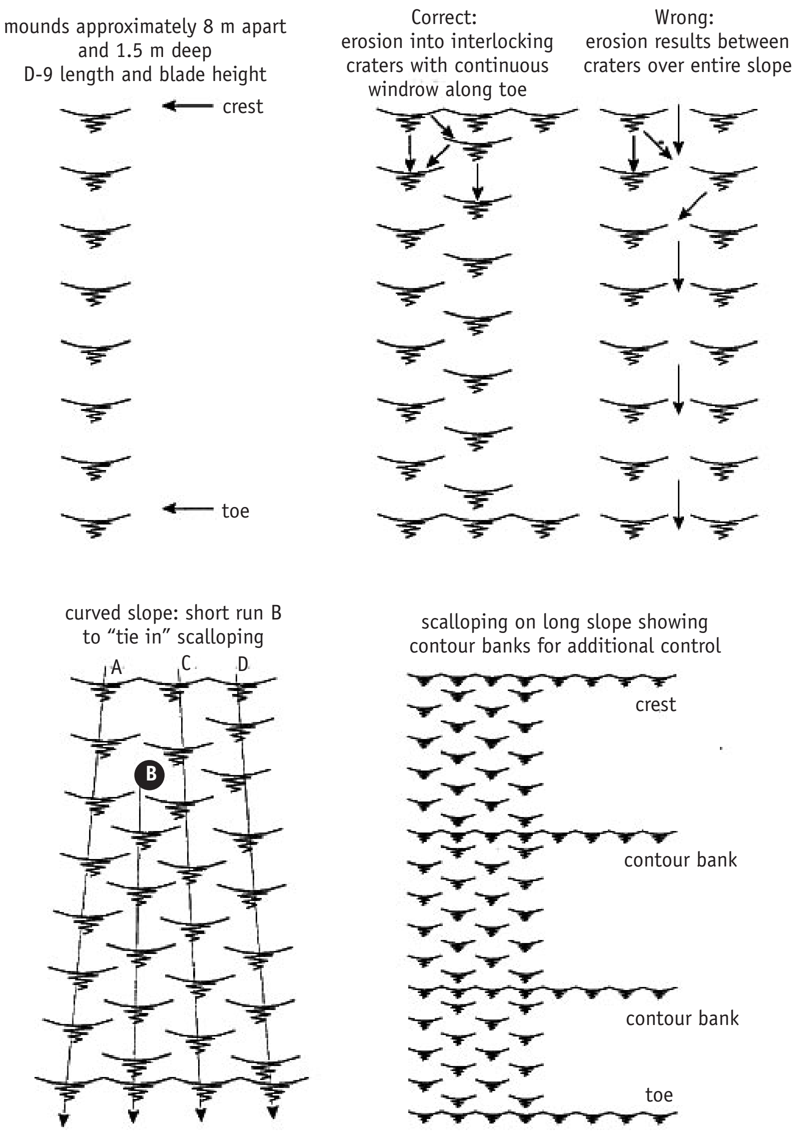
- ripping is carried out to adequate depth to graft the topsoil/subsoil layer on to the underlying waste material;
- on slopes, rip-lines must be located on the contour. Contour ripping is difficult above 14 degrees and generally not possible above 20 degrees.

Scalloping: This is a suitable technique to use on steeper slopes (from 15 to 27 degrees). It uses interlocking banks or blade pushes of material, sized according to slope, waste material and machinery available (Figure 13). It improves soil structure, reduces water and wind erosion and allows small micro-catchments to be created that provide niches for vegetation to establish. There are several requirements for it to work effectively:

- development of the scallops should begin at the toe of the slope and work outward towards the crest;
- subsequent runs up the slope should be worked close to the previous run and offset by 50 percent to lock the lattice of banks together;
- continuous contour banks may be required on long slopes to guard against erosion of the entire face.

If properly constructed and revegetated or armoured, the dump should be maintenance-free and able to resist natural erosion forces.

Figure 13. Scalloping or moonscaping



Source: Department of Minerals and Energy, Western Australia. 1996. *Guidelines for Mining in Arid Environments.*

Contaminant containment: Acid rock drainage, metals and contaminants from waste material can have severe and persistent effects on vegetation and ground water. In arid environments, such problems may not become apparent for several years. If waste characterisation identifies a potential problem, the following measures should be undertaken:

- additional characterisation, including static testing;
- rigorous evaluation of stability, drainage and covering systems of disposal sites and rehabilitation/restoration proposals;
- monitoring and management plans to prevent adverse impacts during and after the project life;
- measures to minimise the risk of pollution to surface or ground waters, including source control, pathway control and remediation at the receptor.

Annex 6. Key organisations

Organisation	Address	Web site address
Centre for Energy, Petroleum and Mineral Law and Policy (affiliated to Dundee University)	CEPMLP, University of Dundee, Dundee, DD1 4HN, Scotland Tel: 44 (0)1382 344300 Fax: 44 (0)1382 322578	www.dundee.ac.uk
Centre for Sustainable Development	Centre for Sustainable Development, University of Westminster, 35 Marylebone Road, London, NW1 5LS, Tel: 020 7911 5000; Fax: 020 7911 5057	www.wmin.ac.uk/cfsd
Club du Sahel	2, rue André Pascal, F-75775 Paris Cedex 16, France Tel 33 1 45 24 82 00	www.oecd.org/sah
Conservation International	1919 M Street, NW Suite 600, Washington, DC 20036, Tel: (202) 912-1000	www.conservation.org
United Nations Convention to Combat Desertification	UNCCD Secretariat, P.O. Box 260129, Haus Carstanjen, D-53153 Bonn, Germany Tel: (49 228) 815 2802 Fax: (49 228) 815 2898/99	www.unccd.int/main.php
Desert Research Institute (DRI)	Northern Nevada Science Center, 2215 Raggio Parkway, Reno, Nevada 89512, USA Tel: (775) 673 7300	www.dri.edu
Global Mining Initiative	Global Mining Initiative, c/o 6, St. James's Square, London SW1Y 4LD Tel: 44 (0) 207753 2273	www.globalmining.com
Industrial Development Organisation	Vienna International Centre, P.O. Box 300, A-1400 Vienna, Austria, Tel: 43 (1) 26026-0 Fax: 43 (1) 2692669	www.unido.org
Institute of Environmental Management and Assessment (IEMA)	IEMA, St. Nicholas House, 70 Newport, Lincoln LN1 3DP, Tel: 44 (0)1522 540069; Fax: 44 (0)1522 540090	www.iema.net
International Arid Lands Consortium (IALC)	1955 E. 6th St, Tucson, AZ 85719 USA, Tel: 520-621-3024; Fax: 520-621-7834	www.ag.arizona.edu/OALS/IALC/Home.html
International Association of Impact Assessment	1330 23rd Street South, Fargo, ND, 58103 USA, Tel: 701-297-7908; Fax: 701-297-7917	www.iaia.org

International Association of Oil and Gas Producers (OGP); formerly E&P Forum	25/28 Old Burlington Street, London W1S 3AN, United Kingdom, Tel: 44 (0)20 7292 0600 Fax: 44 (0)20 7434 3721	www.ogp.org.uk
International Centre for Trade and Sustainable Development (ICTSD)	International Environment House, Chemin des Anémones 13, 1219 Châtelaine, Geneva, Switzerland, Tel: (41-22) 917-8492 Fax: (41-22) 917-8093	www.ictsd.org
International Council on Mining and Metals (ICMM)	International Council on Mining and Metals, 3rd Floor, 19 Stratford Place, London W1C 1BQ Tel: 44 (0) 20 7290 4920	www.icmm.com
International Development Research Centre (IDRC)	PO Box 8500, Ottawa, ON K1G 3H9, Canada Tel: 1 (613) 236 6163	www.idrc.ca
International Finance Corporation (IFC)	2121 Pennsylvania Ave. NW, Washington, DC 20433 USA Tel: 202-473-0725 Fax: 202-974-4323	www.ifc.org/mining
International Institute for Environment and Development (IIED)	3 Endsleigh Street, London WC1 0DD, Tel: 44 (0) 207 388 2117 Fax: 44 (0) 207 388 2826	www.iied.org
International Network for Environmental Management (INEM)	Osterstrasse 58, 20259, Hamburg, Germany, Tel: 49-40-4907-1600 Fax: 49-40-4907-1601	www.inem.org
International Petroleum Industry Environmental Conservation Association (IPIECA)	2nd Floor, Monmouth House, 87-93 Westbourne Grove, London W2 4UL, Tel: 44 (0) 207 221 2026 Fax: 44 (0) 207 229 4948	www.ipieca.org
International Union for the Conservation of Nature and Natural Resources (IUCN)	IUCN – The World Conservation Union Headquarters, Rue Mauverney 28, Gland, 1196, Switzerland, Tel: 41 (22) 999-0000 Fax 41 (22) 999-0002	www.iucn.org
Mineral and Energy Policy Centre	7th Floor, Block 9, 200 Hans Strijdom Drive, Randburg South Africa Tel: 27 (0) 11 709 4665 Fax: 27 (0) 11 709 4595	www.mepc.org.za
Mineral Industry Research Organisation (MIRO)	1 City Square, Leeds, Yorkshire LS1 2ES, United Kingdom Tel: 44 (0) 113 300 2040 Fax: 44 (0) 113 300 2640	www.miro.co.uk

Mineral Information Institute	501 Violet Street, Golden, CO 80401, USA, Tel: 303/277-9190 Fax: 303/277-9198	www.mii.org/recl.html
Mineral Policy Institute	PO Box 89, Erskineville, NSW 2043, Australia, Tel: (61 2) 9557 9019 Fax: (61 2) 9557 9822	www.mpi.org.au
Mineral Resources Forum	c/o UNCTAD, Palais des Nations, E-Building, Geneva, Switzerland Tel: 41-22-907-1234	www.mineralresources forum.org
Mining and Energy Research Network (Warwick University Business School)	Warwick Business School, The University of Warwick, Coventry, CV4 7AL, UK, Tel: 44 (0)24 7652 4306 Fax: 44 (0) 24 7652 3719	www.users.wbs.ac.uk/ group/mern
Mining Minerals and Sustainable Development	1A Doughty Street, London, WC1N 2PH, Tel: 44 (0) 20 7269-1630 Fax: 44 (0) 20 7831-6189	www.iied.org/mmsd
Organisation for Economic Cooperation and Development (OECD)	2, rue André Pascal, F-75775 Paris Cedex 16, France Tel 33 1-45-24-82-00	www.oecd.org
Réseau International des ONG sur la Désertification (RIOD)	4837 Rue Boyer, Suite 250 Montréal, Québec, Canada H2J 3E6, Tel: (514) 522-6077 Fax: (514) 522-2370	www.riodccd.org
UN Development Programme, Office to Combat Desertification and Drought (UNSO)	304 East 45th Street, New York NY 10017 USA Tel: 1 212 906 6497 Fax: 1 212 806 6345	www.undp.org
UN Environment Programme (UNEP)	United Nations Avenue, Gigiri, PO Box 30552, Nairobi, Kenya Tel: 254 2 621234 Fax 254 2 624489/90	www.unep.org
World Bank (Mining and Industry Unit and Dryland Management/Combating Desertification Thematic Group)	1818 H Street, NW Washington, DC 20433 USA Tel: (202) 473-1000 Fax: (202) 477-6391	www.worldbank.org
World Business Council for Sustainable Development (WBCSD)	160 Rue de Florissant, CH-1231, Conches, Geneva, Switzerland Tel: 41 22 839 3100 Fax: 41 22 839 3131	www.wbcsd.ch
World Wildlife Fund (WWF)	Avenue du Mont-Blanc, 1196 Gland, Switzerland Tel: 41 22 364 91 11	www.panda.org

Annex 7. Website information

Desert Research Foundation of Namibia (DRFN)
http://www.drfn.org.na/siteMap.html
The DRFN is a centre for arid land studies that conducts and facilitates appropriate, participatory and applied short- and long-term research on the environment. List of publications available in hard copy only from DRFN. Publications relate primarily to water management but some research papers on desertification indicators and biological protection.

Desert Research Institute (DRI), Nevada
http://www.dri.edu
DRI conducts basic and applied environmental research concerning drylands on a local, national, and international scale.

Food and Agriculture Organisation (FAO)
http://www.fao.org/desertification/default.asp?lang=en
Searchable database by theme, date of publication and title. Publications on all aspects of desertification, agriculture, forestry, soil and water management and sustainable development in arid lands. Links to national desertification websites and searchable database for links to other desertification-related sites.

International Arid Lands Consortium (IALC)
http://ag.arizona.edu/OALS/IALC/links/desert.html
Links to a number of sites on desertification and drought.

International Fund for Agricultural Development
http://www.ifad.org/pub/cat/cat.html
Catalogue of books and booklets on desertification including Tackling land degradation and desertification and Drylands: A Call to Action.

International Institute for Environment and Development (IIED) Drylands Development Programme
http://www.iied.org/drylands/index.html
Information on and links to desertification sites. Drylands issue papers are available to download. Focus is on Africa and natural resource management and land tenure issues.

Centre for Arid Zone Studies (CAZS), University of Wales
http://www.cazs.bangor.ac.uk/english/intro_e.html
The centre was primarily established to promote integrated agricultural and forestry development in arid and semi-arid lands and to provide technological and scientific innovation to improve natural resource allocation and management.

Instituto Argentino de Investigaciones de las Zonas Áridas
http://www.cricyt.edu.ar/INSTITUTOS/iadiza
IADIZA conducts research and development activities in five core areas, with the ultimate goal of restoration and sustainable development of arid lands; site is in Spanish.

United Nations Convention to Combat Desertification (UNCCD)
http://www.unccd.int/publicinfo/factsheets/menu.php
Links to a number of fact sheets on desertification: causes, consequences and measures to combat desertification in various regions.

Exploration and survey

Mineral Resources Forum
http://www.natural-resources.org/minerals/generalforum/csr/practices.htm
Site contains best practice guidelines for exploration including a code of practice, reporting guidelines and environmental management.Environmental Management Programme for Exploration. Appendix to Berlin Guidelines (2002).

Victoria Natural Resources and Environment Department
http://www.nre.vic.gov.au
Exploration and restoration of mining sites.

Appraisal and feasibility studies

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
EIA and Mine Planning for Environment Protection Handbooks from Best Practice Environmental Management in Mining handbooks. Hard copies of the series available from Environment Australia.

Mineral Resources Forum
http://www.natural-resources.org/minerals/generalforum/csr/practices.htm
Site has links to best practice guidelines for approvals and assessment. Guidelines to Help Get Environmental Approval for Mining Projects in Western Australia. Appendix to Berlin Guidelines (2002).

Western Australia Department of Minerals and Energy
Guidelines for Mining Project Approval in Western Australia (H) and Environmental Assessment Processes for Petroleum Activities in Western Australia (D).

Mining operations
European Bank for Reconstruction and Development (EBRD)
http://www.ebrd.com/enviro/index.htm
EBRD has developed a set of sub-sectoral environmental guidelines to assist credit/investment offices in local financial institutions and other non-environmental experts. They are designed to help in identifying major environmental activity risks, important management actions, and essential aspects of environmental due diligence. The mining sector guidelines cover coal and metal processing and mining (open cast and underground).

International Council on Mining and Metals
http://www.icmm.com
Case studies on environmental practices in metallurgical/mineral processes. Available to download.

Mineral Resources Forum
http://www.mineralresourcesforum.org/minerals/generalforum/csrpractices.htm
Affiliated to UNEP. Subscription to e-mail discussion group on mining and the environment. Number of links to best practice guidelines for mine development and construction, mining, processing, tailings and waste management and acid mine drainage.

Mining and Energy Research Network (Warwick University Business Schoool)
http://users.wbs.warwick.ac.uk/ccu/mern/publications.htm
Series of publications (working papers) available to order (not downloadable). Some case studies on Ghana, Brazil, South Africa.

World Bank
http://www.worldbank.org
Sectoral guidelines contained in Pollution Prevention and Abatement Handbook (PPAH) for base metal and ore mining and coal mining and production. Additional guidelines available for underground and open pit mining and milling.

Petroleum production

Center for Environmental Leadership in Business
www.cwlb.org/ebi.html
Energy and Biodiversity Initiative — developing tools and guidelines for integrating biodiversity into oil and gas development. Consists of a set of four working groups looking at, among other things, identification and implementation of best technical and management practices; performance indicators for measuring the impacts of oil and gas development on biodiversity and criteria for deciding whether to undertake mining activities in sensitive environments.

Institute of Petroleum UK
http://www.petroleum.co.uk
Guidance notes on environmental considerations for pumping installations.

International Association of Oil and Gas Producers
http://www.ogp.org.uk/publications/index.html
General publications on environmental management in oil and gas exploration and production. Environmental guidelines on: Operating in sensitive environments; Oil and Gas Exploration and Production in Arctic and Subarctic Onshore Regions - Guidelines for Environmental Protection.

International Financing Corporation (IFC)
http://www.ifc.org/ogc/publications.htm
A number of selected publications (working papers, technical papers, manuals and assessment papers) on oil and gas.

International Petroleum Industry Environmental Conservation Association
http://www.ipieca.org/publications/biodiversity.html
Links to publications on biodiversity issues including The Oil Industry: Operating in Sensitive Environments (IPIECA/E&P Forum), Biodiversity and the Petroleum Industry, and a number of case studies on environmental management and protection during oil exploration and production activities.

UNEP (Department of Economic and Social Affairs)
http://www.mineralresourcesforum.org/workshops/Berlin/index.htm
This document reports on the conduct and outcome of the Berlin Roundtable on Mining and the Environment, held on 22–26 November 1999.

Western Australian Department of Mineral and Petroleum Resources
http://www.mpr.wa.gov.au/prodserv/pub/index.html
Guidelines for environmental management for both offshore and onshore petroleum operations.

World Bank
http://wbln0018.worldbank.org/essd/essd.nsf/Docs/TOC
Sectoral guidelines contained in Pollution Prevention and Abatement Handbook (PPAH) for oil and gas development.

General operational site requirements

Mineral Resources Forum
http://www.natural-resources.org/minerals/generalforum/csr/practices.htm
Links to a number of best practice guidelines for mining site requirements including health and safety, noise and dust control, firebreak development and quarry codes of practice.

Decommissioning and rehabilitation/restoration

Australian Institute of Petroleum (AIP)
http://www.aip.com.au/pdf/Publist_2001.pdf
Publications list contains references for petroleum and oil processing and storage including safe handling and transportation of products.

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Restoration handbooks from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

Institute of Petroleum UK
http://www.petroleum.co.uk
Guidance notes on environmental considerations when decommissioning plants.

International Association of Oil and Gas Producers
http://www.ogp.org.uk/publications/index.html
General publications on decommissioning, remediation and reclamation guidelines for onshore exploration and production.

Mineral Information Institute
www.mii.org/recl.html
Site focuses on restoration. Gives a number of case studies of successful restoration projects for different types of minerals and soil types. Focus is on providing information on U.S. mining for teachers/schools.

Mineral Resources Forum
http://www.natural-resources.org/minerals/generalforum/csr/practices.htm
Number of links to best practice guidelines for mine closure/decommissioning. Also Environmental Aspects of Mine Closure. Appendix to Berlin Guidelines (2002).

UNEP
http://www.mineralresourcesforum.org/docs/pdfs/abandoned_report.pdf
This report summarizes the presentations and discussions of the first Pan-American Workshop on Abandoned Mines, held in Santiago, Chile, 18 June 2001.

Victoria Natural Resources and Environment Department
http://www.nre.vic.gov.au
Exploration and restoration of exploration sites and other rehabilitation and mine closure publications.

Western Australia Department of Minerals and Energy
www.dme.wa.gov.au and http://www.mpr.wa.gov.au
Mine Rehabilitation Handbook. Available from Australian Industry Mining Council.

Environmental and natural resource management agencies

Australasian Institute of Mining and Metallurgy
http://www.ausimm.com.au
No guidelines on environment but good links to Australian mining and environment related sites (institutes, companies, government agencies).

Chamber of Minerals and Energy of Western Australia
http://www.mineralswa.asn.au/~cmeenpu/page3.html#use
Code of practice for Exploration in Environmentally Sensitive Areas available from this site.

Environment Australia Online
www.ea.gov.au/industry/sustainable/mining
Representatives of the Australian minerals industry and theCommonwealth Government's Environment Australia are working together to collect and present information on a variety of topics that illustrate and explain best practice environmental management in Australia's minerals industry. The information is published in a series of booklets as the Best Practice Environmental Management in Mining Program (BPEM). The BPEM booklets are valuable and practical reference materials used to encourage, assist and lead all sectors of the resources industry towards achieving sustainable development.

Environmental Mining Council of British Columbia
http://www.miningwatch.org/emcbc
Site has links to ten modules from "Mining and the Environment Primer".

Minerals Council of Australia
http://www.minerals.org.au/defaultx.html
Publications are about minerals only. Nothing on mining processes. Example of an industry framework for improving environmental management. Good links to mining related State Minerals Councils/ Chambers, Industry Associations, State and Federal Government Departments and Educational bodies in Australia. Also has some international mining links.

Namibian Ministry of Mines and Energy
http://www.mme.gov.na
Available publications are White Papers, regulations and plans.

Nevada Bureau of Mines and Geology
http://www.nbmg.unr.edu
Downloadable publications, all very technical.

New South Wales Department of Mineral Resources
http://www.minerals.nsw.gov.au
Lists a number of Environmental Best Practice and Reference Documents available from various Australian Mining Councils and government agencies.

Northern Territory Department of Business, Industry and Resource Development (Mines and Energy)
http://www.dme.nt.gov.au

Queensland Environmental Protection Agency
http://www.epa.qld.gov.au
Guidelines are available but none dedicated to arid zones. Also includes a link to factsheets on mining and the environment (including preparation of an EIS and codes of environmental compliance). Good links to academic, education, government and mining and petroleum sites in Australia.

South African Chamber of Mines
http://www.bullion.org.za
Site has information on mining and the environment including proceedings of conferences on mining, environment and sustainable development.

South African Department of Minerals and Energy Affairs
http://www.dme.gov.za
Only guidelines are safety guidelines (preventing explosions, etc.).

United States Bureau of Land Management
http://www.blm.gov/nhp
Documentation on acquisition and rights of way.

Victoria Natural Resources and Environment Department
http://www.nre.vic.gov.au
Links to a number of environmental management of mining guidelines. Available for downloading. Covers impact assessment, regulatory frameworks, environmental management systems and rehabilitation reports and audit statement preparation.

Western Australian Department of Environmental Protection
www.environ.wa.gov.au
Contains applications for exploration, bulletin reports and reviews of mining operations and leases.

Western Australian Department of Mineral and Petroleum Resources
www.dme.wa.gov.au and http://www.mpr.wa.gov.au
Guidelines for Mining in Arid Environments. Has downloadable publications on environmental management in petroleum and mineral mining, including "Guidelines for mineral exploitation and mining within conservation reserves and other environmentally sensitive lands in Western Australia".

Private sector: Mining and petroleum industries

International and large-scale national companies

Anglo American Plc
http:/www.angloamerican
co.uk/social/shereport.asp
Annual Health, Safety and Environment Report contains some relevant sections as well as case studies. See Namakwasands case study in particular for rehabilitation of arid areas.

Rio Tinto
www.riotinto.com
Fact sheets (pdf) on mining and the environment. Annual social and environmental reviews.

BP Plc
http://www.bp.com
Annual Environmental and Social Reports with case studies. Also guidelines on environmental performance reporting. Section on working in ESAs but not relating specifically to arid zones.

Caltex
http://www.caltex.com
Code of practice for management of used oil in New Zealand.

Chevron Texaco Corporation
http://www.chevron.com; see also http://www.chevrontexaco.com
Gives some details of 'Responsible Care' programme (Guiding Principles and Code of Practice).

Enterprise Oil Plc
http://www.entoil.com/; info now available on http://www.shell.com/entoil
Recently acquired by Shell Plc. Latest publications on Shell site - Environmental Reviews; case studies (climate change).

Kennecott Minerals Company (KMC)
www.kennecottminerals.com
Gives some examples of best practice in reclamation but not specific to arid zones.

Minera Escondida
http://www.escondida.cl/english/enviromental.htm
Gives brief description of type of environmental procedures used in copper mining in Atacama desert.

Mobil
http://www2.exxonmobil.com
Publications include Safety, Health and Environment Reports (annual) and reports on Valdez and other oil spill clean-up operations.

Santos Limited
http://www.santos.com.au/v1/default.asp; follow "Responsibilities" link to environment site
Link to a number of specialist environmental handbooks including "The Arid Zone Field Environmental Handbook".

Shell International Ltd.
http://www.shell.com
Annual reports illustrate Shell's cognisance of environmental and social issues.

Artisanal mining

Assistance Technique aux Petites Exploitations Minieres (ATPEM)
http://www.projekt-consult.de/atpem
Provides a case study of the normalisation of the small-scale mining sector in Madagascar.

Communities and Small-Scale Mining (CASM)
http://www.casmsite.org
The site contains a 'knowledge centre' with a number of live databases. The community database allows one to find people with similar interests or experiences, or with special expertise. The bibliographic database assists in finding what has been written about artisanal and small-scale miners during the last 10 to 20 years, and links to existing on-line documents, as well as significant historic and unpublished documents that will be stored in and can be downloaded from an on-line depository.

International Institute for Environment and Development (IIED) Mining, Minerals and Sustainable Development (MMSD) Research and Consultation Project
http://www.iied.org/mmsd/activities/small_scale_mining.html
Links to research output, including a global report, common terms of reference for country studies, and country studies from southern Africa (Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe); west Africa (Burkina Faso, Ghana and Mali); South America (Bolivia, Brazil, Ecuador, Peru); and Asia-Pacific (China, India, Indonesia, Philippines, Papua New Guinea). Workshop minutes and reports from Chile and London meetings are also available.

Mineral Resources Forum - Small-Scale Mining (MRF-SSM)
http://www.natural-resources.org/minerals/smscalemining/index.htm
MRF-SSM is a subsection of the Mineral Resources Forum, an on-line knowledge center created and managed by the United Nations Conference on Trade and Development (UNCTAD), out of Geneva. The small-scale mining subsection covers the range of issues related to artisanal and small-scale mining, including environment, health and safety, women and children, organizational, technical and financial issues, regulatory and legal reform. Of particular interest are the news and document pages, which provide direct links to current stories and significant documentation.

Southern African Network for Training and Research on the Environment (SANTREN)
Small-Scale Mining Group
http://www.und.ac.za/und/geog/ssm/intro.html
The role of the Small-Scale Mining Group is to review the impacts of small-scale mining in certain SADC countries and to deveop short courses aimed at specific target groups. Some of these materials are available on the site including: Establishing Training Guidelines on Environmental Protection and Management for Small-Scale Mining in Zimbabwe. Outlines the basic principles that should be incorporated into environmental management guidelines for small-scale mining.

World Bank
http://www.worldbank.org/html/fpd/mining/index.htm
Consultative Group on Artisinal and Small Scale Mining Development.

World Bank Group
http://www.worldbank.org
Summary of the Proceedings of the International Roundtable on Artisanal Mining organised by the World Bank, Washington, D.C, May 17–19, 1995. Industry and Energy Department, Occasional Paper No. 6, Ed. Mamadou Barry, April 1996. The proceedings include sessions on environmental, health and safety issues; organizational, social and women's participation issues; technical and financial issues; and legal and regulatory issues.

Banks and financing agencies

African Development Bank (AFDB)
www.afdb.org

Asian Development Bank (ADB)
http://www.adb.org.

Development Bank of Southern Africa (DBSA)
http://www.dbsa.org/PrivateSector/PrivateSectormaster.htm

European Bank for Reconstruction and Development (EBRD)
http://www.ebrd.com
The EBRD has developed a set of sub-sectoral environmental guidelines to assist credit/investment officesr in local financial institutions and other non-environmental experts. They are designed to help in identifying major environmental activity risks, important management actions, and essential aspects of environmental due diligence. The mining sector guidelines cover coal and metal processing and mining (open cast and underground).

Inter-American Development Bank (IADB)
http://www.iadb.org

World Bank (International Finance Corporation)
http://www.ifc.org
IFC is using all the environmental guidelines contained in the Pollution Prevention and Abatement Handbook (PPAH). These cover, among other things, base metal and iron ore mining, coal mining and production and oil and gas development (onshore). It also uses the World Bank guidelines on Underground and Open Pit Mining and Milling.

Universities and research organisations

Colorado School of Mines
http://www.mines.edu

Desert Research Foundation of Namibia
http://www.drfn.org.na/siteMap.html
The DRFN is a centre for arid land studies that conducts and facilitates appropriate, participatory and applied short- and long term research on the environment. List of publications available in hard copy only from DRFN. Publications relate primarily to water management but some research papers on desertification indicators and biological protection.

Desert Research Institute, Nevada
http://www.dri.edu

Instituto Argentino de Investigaciones de las Zonas Áridas
http://www.cricyt.edu.ar/INSTITUTOS/iadiza
IADIZA conducts research and development activities in five core areas, with the ultimate goal of restoration and sustainable development of arid lands; site is in Spanish.

South Dakota School of Mines and Technology
http://www.sdsmt.edu

Western Australian School of Mines
http://www.kalg.curtin.edu.au/about/wasm.html

International and regional institutions

Intergovernmental organisations

International Fund for Agricultural Development
http://www.ifad.org/governance/index.htm
Publications on tackling land degradation and desertification.

United Nations Conference on Trade and Development (UNCTAD)
http://www.unctad.org

United Nations Department for Technical Cooperation for Development (UNDTCD)
www.un.org/esa
These guidelines address: mining and sustainable development; regulatory frameworks; environmental management; voluntary undertakings; and community consultation and development; as applied to all stages of a mining operation comprising: exploration; operation; decommissioning; and closure and rehabilitation; and include a section on small-scale and artisanal mining.

United Nations Development Programme Office to Combat Desertification and Drought (UNSO)
http://www.undp.org/seed/unso

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)
http://unescap.org
A range of publications are available for order through ESCAP including: Mineral Resource Assessment, Development and Management; Mineral Concentrations and Hydrocarbon Accumulations.

United Nations Environment Programme (UNEP) - Division of Technology, Industry and Economics
http://www.uneptie.org
The site has a link to UNEP's publications on Mining and the Environment. These materials provide information on addressing the environmental challenges faced and on the cleaner technology practices which assist in environmentally sound decision-making and procedures.

United Nations Industrial Development Organisation (UNIDO)
http://www.unido.org
Publications on industrial development and environmental management. Nothing related to mining; one case study on mining and environmental protection in China.

International conventions

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
http://www.unep.ch/basel/index.html
Guidelines to implementation of the Convention and forms for notification of movement. Also links to UN agencies, national environment ministries, NGOs and other sites related to the transport, storage and disposal of hazardous wastes.

Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS)
http://www.wcmc.org.uk/cms

Convention on Biological Diversity (CBD)
http://www.biodiv.org

Convention on Environmental Impact Assessment in a Transboundary Context
http://www.unece.org/env/eia/eia.htm

Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)
http://www.cites.org
Publications on implementing the Convention and links to convention-related sites and organisations.

Convention on the Protection and Use of Transboundary Watercourses and International Lakes
http://www.unece.org/env/water/pdf/watercon.pdf

Convention on the Transboundary Effects of Industrial Accidents
http://sedac.ciesin.org/pidb/texts/industrial.accidents.1992.html

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International Convention on Oil Pollution Preparedness, Response and Cooperation
http://sedac.ciesin.org/pidb/texts/oil.pollution.preparedness.1990.html

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Montreal Protocol on Substances that Deplete the Ozone Layer
http://www.unep.ch/ozone/montreal.html

Ramsar Convention on Wetlands of International Importance
http://www.ramsar.org

United Nations Convention to Combat Desertification (UNCCD)
http://www.unccd.int/main.php

United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol
http://www.unfccc.int

World Heritage Convention
http://www.whc.unesco.org/world_he.htm
Report of the Technical Workshop on World Heritage and Mining.

International private-sector associations

Global Mining Initiative
http://www.globalmining.com

International Association of Oil and Gas Producers (OGP): formerly E&P Forum
http://www.ogp.org.uk

International Council on Metals and the Environment (ICME)
http://www.icme.com
ICMM's predecessor organisation, ICME, published a comprehensive series of scientific publications which ICMM is making available through its web site.

International Petroleum Industry Environment Conservation Association (IPIECA)
http://www.ipieca.org

International NGOs

Conservation International (CI)
www.conservation.org

International Institute for Environment and Development (IIED)
http://www.iied.org

Mining, Minerals and Sustainable Development (MMSD)
http://www.iied.org/mmsd

The World Conservation Union (IUCN)
www.iucn.org
IUCN Position Statement on Mining and Associated Activities in Protected Areas.

World Business Council for Sustainable Development (WBCSD)
http://www.wbcsd.ch

World Wide Fund for Nature (WWF)
http://www.panda.org

Environmental Impact Assessment

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Handbook from Best Practice Environmental Management in Mining Programme run by Environment Australia.

Institute of Environmental Management and Assessment (IEMA)
http://www.iema.net
Links to case studies and best practice journals.

International Association of Impact Assessment
http://www.iaia.org
Contains general best practice guidelines for environmental and social impact assessment.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
EIA guidelines from Appendix to Berlin Guidelines (2002).

Environmental policies, strategies and management systems

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Links to a number of booklets on environmental management systems and environmental management related to mining activites.

Environmental Management
http://www.dundee.ac.uk/cepmlp/main/welcome.htm
Each of these standards and items is explained, and a series of simple-to-use resources and guides identified.

International Network for Environmental Management (INEM)
http://www.inem.org
INEM publications include case study collections and tools specially developed to help small- and medium-sized enterprises implement environmental managment measures.

International Organisation for Standardisation
http://www.iso.ch
Chapters of the 2002 edition can de downloaded as PDFs. Contains information on the model, the benefits of applying it and also provides guides, technical reports and links to other resources.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
Guidelines for Establishing an EMS, Principles of a Regulatory System and Environmental Policies for Mining Industry Operators. Appendices to Berlin Guidelines (2002).

Queensland Environmental Protection Agency
http://www.epa.qld.gov.au
Outline of EPA Policies and Guidelines for Environmental Authorities in Mining. A series of technical guidelines were developed in 1995 in consultation with the mining industry, government departments, research institutions and industry stakeholders. They provide technical advice on a range of environmental management issues. The series is being revised by the Department of Minerals and Mines and will be published on the EPA website as they become available. Advice is relevant to the EIA of mining industry proposals, operations and final rehabilitation.

The ISO 14000 Environmental Management Group
http://www.iso14000-iso14001-environmental-management.com
This web site is designed to untangle and simpify the myriad of ISO 14000 standards and information related to environmental management, to make environmental management using the standards a much easier task. Links to ISO 14000 toolkits and implementation guidelines.

World Bank
http://www.worldbank.org
Outlines key elements of EMS and ISO14000 in examines some of the practical issues that have emerged.

Monitoring, auditing and reporting

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Environmental Monitoring and Performance Handbook from Best Practice Environmental Management in Mining Programme.

Global Reporting Initiative (GRI)
http://www.globalreporting.org
Sustainability Reporting Guidelines.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
General Guideline for an Environmental Monitoring Programme. Appendix to Berlin Guidelines (2002).

Decommissioning and rehabilitation

Environment Australia Online
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Rehabilitation and Revegetation and Mine Decommissioning Handbooks from Best Practice Environmental Management in Mining Programme.

Institute of Petroleum UK
http://www.petroleum.co.uk
Guidance notes on environmental considerations when decommissioning plants and also for pumping installations.

Mineral Information Institute
www.mii.org/recl.html
Site focuses on mine rehabilitation. Gives a number of case studies of successful mine rehabilitation projects for different types of minerals and soil types. Focus is on providing information on U.S. mining for teachers/schools.

Soils and erosion

Central Arid Zone Research Institute
http://aoi.com.au/acotanc/Papers/Tewari-1/Author-n-Text.htm
Research paper on dune stabilisation in arid areas in India.

Food and Agriculture Organisation (FAO)
http://www.fao.org/wairdocs/x5309e/x5309e06.htm
Dune fixation: a tool for desertification control. Describes some of the commonly used fixation techniques.

Integrated Science and Technology, Inc
http://www.integratedscience.com/publications/Biopile.htm
H. James Reisinger, Stewart A. Mountain, Giorgio Andreotti, Giancarlo DiLuise, Augusto Porta, Aaron S. Hullman, Victor Owens, Daniele Arlotti, John Godfrey: Bioremediation of a major inland oil spill using a comprehensive integrated approach.

International Oil Spill Resource and Information Center
http://www.oil-spill-web.com/handbook/front.htm
Site provides a directory of services and contacts relating to oil spills both on- and off-shore including guidelines on recommended response tactics to the most common types oil pollution on land.

International Tanker Owners Pollution Federation Limited
http://www.itopf.com/disposal.html
Response strategies for oil spills including bioremediation techniques.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
Appendix 6 to Berlin Guidelines: Air, Water and Soil Quality Standards.

South Australia Department for Environment and Heritage
http://www.environment.sa.gov.au/coasts/ coastcare/stabilisation.pdf
Dune stabilisation techniques and dune assessment checklist. Developed primarily for coastal dunes but techniques apply to desert dunes.

United States Environmental Protection Agency
http://www.epa.gov/oilspill/bioagnts.htm
Biological agents for land remediation after oil spills.

United States Environmental Protection Agency
http://www.epa.gov/oilspill/pdfs/biofact.pdf
Fact sheet on bioremediation techniques for land spills. Mostly deals with offshore spills but short section on techniques for onshore spills.

United States Department of the Interior, Minerals Management Service
http://www.gomr.mms.gov/homepg/regulate/regs/ntls/9830att.pdf
Guidelines for Preparing Regional Oil Spill Response Plans.

United States Department of the Interior, Minerals Management Service
http://www-esd.lbl.gov/ECO/eco_pubs/1999/tien99.pdf
A.J. Tien, D.J. Altman, A. Worsztynowicz, K. Zacharz, K. Ulfig, T. Manko, T.C. Hazen: Bioremediation of a Process Waste Lagoon at a Southern Polish Oil Refinery, DoE's First Demonstration Project in Poland.

Solid waste management

Australian Centre for Mining Environmental Research
http://www.acmer.com.au
Handbooks on management of sulfidic mine wastes.

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Various waste and hazardous materials management handbooks from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

Material Safety Data Sheets (MSDS)
http://joule.pcl.ox.ac.uk/MSDS
Technical data about hazardous chemicals, OSHA workplace exposure limits, LD50, reactivity, flammability and transportation guidelines.

UNEP
http://www.mineralresourcesforum.org/Initiatives/cyanide/docs/cyanide-report.pdf
This document reports on the conduct and outcome of an international workshop on Industry Codes of Practice: Cyanide Management on 25–26 May 2000 at École des Mines, Paris, France.

UNEP/ICME/SIDA
http://www.mineralresourcesforum.org/docs/Sweden1997/Allpages.pdf.

Western Australia Department of Mineral and Petroleum Resources
http://www.mpr.wa.gov.au/prodserv/pub/index.html
Guidelines on the use and management of drilling fluids and cuttings.

Water management

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Water Management Handbook from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
Appendix 6 to Berlin Guidelines: Air, Water and Soil Quality Standards.

Minerals Council of Australia
http://www.minerals.org.au/defaultx.htm
Mine Site Water Management Handbook.

Victoria Natural Resources and Environment Department
http://www.nre.vic.gov.au
Publications on water management in mines and quarries and disposal of mine water.

Air quality management

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Cleaner Production, Energy Efficiency and Greenhouse Gas Reduction and Dust Control Handbooks from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

Greenhouse Gas Technology Center
http://www.sri-rtp.com/Verifications-OilandGasProductionandDistribution.htm
The GHG Center locates promising GHG mitigation technologies, subjects them to independent third-party performance testing, and provides performance results to the public free of charge. The GHG Center operates under the U.S. EPA's Environmental Technology Verification Program, and is evaluating technologies in the following industries: advanced electricity production, waste management, oil and gas production and distribution, GHG monitoring, large engines, refrigeration, and others.

Mineral Resources Forum
http://www.mineralresourcesforum.org/workshops/Berlin/docs/Appendix.pdf
Appendix 6 to Berlin Guidelines: Air, Water and Soil Quality Standards.

United States Environmental Protection Agency
http://www.epa.gov/ghginfo/reports/1opt.htm
Options for Reducing Methane Emissions Internationally: Volume I: Technological Options for Reducing Methane Emissions.

World Bank
http://www.wordbank.org/nipr
New Ideas in Pollution Regulation.

Contingency planning

Environment Australia
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Environmental Risk Management Handbook from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

Mineral Resources Forum (MRF)
http://www.mineralresourcesforum.org/workshops/regulators/2000/docs/reg_rept.pdf
Accident Prevention in Mining – Environmental Regulation for Accident Prevention: Tailings and Chemicals Management (UNEP/Govt of Australia). This document reports on the conduct and outcome of an International Workshop on Environmental Regulation For Accident Prevention in Mining:Tailings and Chemicals Management, held in Perth, Western Australia, 26–27 October 2000.

UNEP/ICME
http://www.mineralresourcesforum.org/docs/Buenosires1999/Allpages.pdf
The workshop Risk Management and Contingency Planning in the Management of Mine Tailings was organized by ICME in cooperation with UNEP and SEGEMAR (Argentine Geological Service) to provide increased awareness and improved understanding of the purpose, methodologies, application and benefits of risk assessment and contingency/emergency response planning with respect to mine tailings, to identify any related issues or concerns, and to define approaches that foster the effective management of tailings impoundments.

United Nations Environment Programme (UNEP)
http://www.mineralresourcesforum.org/initiatives/apell/apellmining.htm
UNEP site introducing the various resources available for emergency preparedness in mining.

United Nations Environment Programme (UNEP) Division of Industry, Technology and Economics (DTIE)
http://www.uneptie.org
Management of Industrial Accidents Prevention and Preparedness (1996).

United Nations Environment Programme (UNEP) Mineral Resources Forum (MRF)
http://www.mineralresourcesforum.org/initiatives/apell/docs/APELL_for_Mining.pdf
Guidance for The Mining Industry in Raising Awareness and Preparedness for Emergencies at Local Level (UNEP Technical Report No. 41).

Western Australia Department of Mineral and Petroleum Resources
http://www.mpr.wa.gov.au/prodserv/pub/index.html
Links to a number of guidelines, reports and procedures for mine safety.

Liaison with local communities and other stakeholders

Communities and Small-Scale Mining
http://www.casmsite.org
Website and knowledge centre. Includes links to sites with information related to communities and small-scale mining.

Environment Australia Online
http://www.ea.gov.au/industry/sustainable/mining/booklets/index.html#archival
Community Consultation and Involvement Handbook from Best Practice Environmental Management in Mining Programme. Hard copies of the series available from Environment Australia.

International Finance Corporation (IFC)
http://www.ifc.org/ogc/publications.htm
See the section on manuals. Has links to publications concerning public consultation and incorporating social concerns into private decision-making.

UNEP
http://www.mineralresourcesforum.org/workshops/regulators/2002/docs/workshop.report.pdf
How Government Regulations Interface with Voluntary Initiatives to Improve the Environmental Performance of the Mining Sector (2002).

Western Australia Chamber of Minerals and Energy
http://www.mineralswa.asn.au/~cmepubs/page4.html
Mining and the Community, a booklet of case studies and research links of stakeholder involvement in mine planning and activities in Australia.

World Bank
http://www.worldbank.org/wbi/sourcebook
The World Bank Participation Sourcebook.

Financing closure and rehabilitation

Victoria Natural Resources and Environment Department
http://www.nre.vic.gov.au/web/root/domino/cm_da/nrenmp.nsf/frameset/NREMineralsandPetroleum
Strategic Framework for Mine Closure, ANMEC and Minerals Council of Australia and Establishment of Rehabilitation Bonds for Mining and Extractive Industry.

IUCN – The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: nearly 1000 members in all, spread across some 140 countries.

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.

The World Conservation Union builds on the strengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels.

IUCN's Ecosystem Management Series

The livelihoods of people all over the world depend on goods and services provided by ecosystems: clean water and air, food, fuel and construction materials. Ecosystems, however, are under increasing pressure from unsustainable use and outright conversion. To address this threat, IUCN promotes the Ecosystem Approach — a strategy for the integrated management of land, water and living resources that places human needs at its centre. The aim of the IUCN Ecosystem Management Series is to share the lessons learned from implementing the Ecosystem Approach, both at field and policy levels, to help realise IUCN's vision of a just world that values and conserves nature.

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