Gold is the aristocratic metal without equal, and together with copper, among the oldest metals known to man-kind. Gold and copper are also the only two metals that are not grayish in colour; others varying from bluish grey (lead) to white (silver). Unlike copper and most other metals, however, gold is quite inert; it does not tarnish, rust, or corrode — it maintains its elemental condition and yellow colour through geological times. It is however also the most useless metal. Only in recent history has gold found applications beyond its use as currency and for decoration.
Minerals, Wealth and Progress

Without the products of mining there would be no civilization as we know it, so a world without mining is unlikely, at least for the foreseeable future. There is, however, a paradox (Mining, Minerals, and Sustainable Development – MMSD – 2002): whereas we enjoy the end products of mining, from simple tools and jewellery to advanced space craft, we are less fond of the ‘holes in the ground’ needed for their supply. A disconnect between source and product is even reflected in the structure of the metals industry, with some manufacturing companies keen to deny their connection to mining on the basis that large amounts of their raw materials come from secondary sources.

The history of mining is replete with controversy, but in recent decades there has been increasing pressure to improve the environmental performance of mining operations, following from greater awareness of global environmental issues. Although Rachel Carson’s 1962 ground breaking text, ‘The Silent Spring’, focused on pesticide damage, it brought attention for the first time to the worldwide scale of environmental degradation associated with the development of an industrial civilization. This introductory chapter will examine the many facets of the relationship between mining and the environment which follow from the demands of that civilization.

The history of mining and the minerals cycle, of which mining is just one part, reveal the complex linkages between mining and society. Mining operations function within the formal and informal institutional frameworks of the country which hosts the mining project, and therefore inevitably acquire a political dimension, as well as strong links to its economy, ecosystem, and local communities; while these latter almost inevitably come to depend on minerals production for employment, income, and broader development. Unfortunately the perceived divergence between mining based development and environmental conservation, usually focused around the mine site and associated communities, often becomes the subject of controversy in which mining companies find themselves at the centre.

Addressing recent history, the chapter touches on the origin and growth of global awareness of environmental issues, and how this has affected regulatory approaches to environmental protection including the now nearly universal environmental impact assessment (EIA) process for new industrial developments. It has become widely recognized
that environmental assessment is essential to integrate economic activity with environmental integrity and social concerns. The goal of that integration can be seen as sustainable development.

Finally, there is a discussion of the World Bank’s guidance on environmental assessment. First formulated in early 1990, the Bank’s approach to environmental assessment of new projects has evolved into a set of standards for industry best practice. Now referred to as the ‘Equator Principles’, these standards have been adopted by most major international financing institutions.

**1.1 HISTORY OF MINING**

Mining has been an essential component of social development since prehistoric times. Minerals have met uniquely human needs through the ages, including securing food and shelter, providing defense, enhancing hunting capacities, supplying jewellery and monetary exchange, enabling transport, heat and power systems, and underpinning industry (Hartman 1987). Thus it is no coincidence that we associate most ages of cultural development with minerals or their derivatives: the Stone Age, the Bronze Age, the Iron Age, the Steel Age, and today’s Nuclear Age. Gold rushes in recent history contributed to settlements in and development of large areas in Canada, California, South Africa, and Australia.

**Early Mining**

Experience of mining varies considerably. Some countries have a long history of mining, either in the form of indigenous small-scale or large-scale, industrial operations, while others show evidence only of recent mining enterprise. There is historical evidence of early mining in Europe, Egypt, and China. In Europe the Iberian peninsula – modern Spain and Portugal – became the focus of the imperial struggle between Rome and Carthage as they fought over its abundance of minerals, including silver, copper, and gold, which in an earlier period had already attracted the interest of the Phoenicians (www.sispain.org).

Mining, of course, has a long history in other parts of the world as well. In the Philippines small-scale mining dates back to the 13th century with the Igorot people, who, for centuries, mined gold and traded it with the Chinese. Historical records show that Southern Africans from Zimbabwe, South Africa, and Tanzania have engaged in mining and smelting for more than a millennium, trading gold with the Arabic world, India, and elsewhere in Asia.

In other areas, mining encouraged the thrust of European colonialism. The invasion of South America, the ‘El Dorado’ of the 16th century, by Spain and Portugal, is well known. The instructions of the Spanish King Ferdinand to Columbus were plain: ‘Get gold, humanely if you can, but at all hazards get gold’ (Kettell 1982). Considerations of a shared humanity were to play little part in the early search for and exploitation of mineral wealth. By the end of the 19th century, very few regions remained untouched by the demand for mineral resources to supply the industrialized world.

However, there are countries where mining commenced relatively recently. In Indonesia, for instance, the first Contract of Work agreement (the legal agreement between the host country and a mining company) was awarded to a US-based company, Freeport McMoran, only in 1967. But even in ‘new’ mining countries, mining on a small scale may have occurred for centuries.

The first mining was probably done by hand, breaking stones for implements, and working surface deposits of high grade mineral deposits such as copper. This was eventually
The introduction of new technologies in the past century has changed the nature of mining. The invention of dynamite in 1867 enabled the advent of large-scale mining as practised today.

Because they were small and concentrated on rich and easily extractable deposits, early mining activities tended to have little impact on the environment. That has changed with the introduction of new technologies over the past two centuries. The invention of dynamite in 1867, for example, was essential to the large-scale mining of today. Hartman (1987, 1992) summarizes some of the most significant developments that have influenced the mining industry and civilization (Table 1.1), but no single chronicle of mining history can be complete. Another good reference, ‘60 Centuries of Copper’ (www.copper.org) provides insight into the history of copper. Along with gold, copper is one of the most important early metals, possibly the first metal used by humans. Another excellent

### TABLE 1.1
How Mining Evolved in Human History

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>450,000 B.C.</td>
<td>First mining (at surface), by Paleolithic man for stone implements</td>
</tr>
<tr>
<td>40,000</td>
<td>Surface mining progresses underground, in Swaziland, Africa</td>
</tr>
<tr>
<td>30,000</td>
<td>Fired clay pots used in Czechoslovakia</td>
</tr>
<tr>
<td>18,000</td>
<td>Possible use of gold and copper in native form</td>
</tr>
<tr>
<td>5000</td>
<td>Fire setting, used by Egyptians to break rock</td>
</tr>
<tr>
<td>4000</td>
<td>Early use of fabricated metals; start of Bronze Age</td>
</tr>
<tr>
<td>3400</td>
<td>First recorded mining, of turquoise by Egyptians in Sinai</td>
</tr>
<tr>
<td>3000</td>
<td>Probable first smelting, of copper with coal by Chinese; first use of iron implements by Egyptians</td>
</tr>
<tr>
<td>2000</td>
<td>Earliest known gold artifacts in the New World, in Peru</td>
</tr>
<tr>
<td>1000</td>
<td>Steel used by Greeks</td>
</tr>
<tr>
<td>A.D. 100</td>
<td>Thriving Roman mining industry</td>
</tr>
<tr>
<td>122</td>
<td>Coal used by Romans in Great Britain</td>
</tr>
<tr>
<td>800</td>
<td>Charlemagne, the first European King, revives mining, contributing to the end of the Dark Ages</td>
</tr>
<tr>
<td>1185</td>
<td>Edict by Bishop of Trent gives rights to miners</td>
</tr>
<tr>
<td>1550</td>
<td>First use of lift pump, at Joachimstal, Czechoslovakia</td>
</tr>
<tr>
<td>1556</td>
<td>First mining technical work, De Re Metallica, published in Germany by Georgius Agricola, translated into English in 1912 by Herbert Hoover; the mining engineer who later became President of the United States of America</td>
</tr>
<tr>
<td>1600</td>
<td>Mining commences in North America, Era of invasion of South America by Spain and Portugal in search of gold</td>
</tr>
<tr>
<td>1627</td>
<td>Explosives first used in European mines, in Hungary (possible prior use in China)</td>
</tr>
</tbody>
</table>

(Continued)
TABLE 1.1
(Continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1716</td>
<td>First school of mines established, at Joachimstal, Czechoslovakia</td>
</tr>
<tr>
<td>1780</td>
<td>Beginning of Industrial Revolution; pumps are first modern machines used in mining</td>
</tr>
<tr>
<td>1800s</td>
<td>American gold rushes help open the West</td>
</tr>
<tr>
<td>1815</td>
<td>Sir Humphrey Davy invented miner’s safety lamp in England</td>
</tr>
<tr>
<td>1843</td>
<td>First mining boom occurs in the US with copper deposits in the Keweenaw Peninsula of Michigan and the Mesabi Iron Range of northern Minnesota</td>
</tr>
<tr>
<td>1851</td>
<td>Beginning of the Australian gold rushes by the discovery of gold by Edward Hargraves (resulting in 370,000 new immigrants to Australia in the following year alone)</td>
</tr>
<tr>
<td>1866</td>
<td>Discovery of the first diamond, the Eureka, in the Kimberley Diamond Fields in South Africa</td>
</tr>
<tr>
<td>1865</td>
<td>Invention of electro refining by Elkington</td>
</tr>
<tr>
<td>1867</td>
<td>Dynamite invented by Nobel, applied to mining</td>
</tr>
<tr>
<td>1900</td>
<td>Era of mechanization and mass production</td>
</tr>
<tr>
<td>1907</td>
<td>Invention of Froth flotation in Australia by Potter</td>
</tr>
<tr>
<td>1909</td>
<td>Invention of converting by Pierce and Smith</td>
</tr>
<tr>
<td>1940s</td>
<td>First application of solvent extraction technology (solution mining) to uranium purification</td>
</tr>
<tr>
<td>1949</td>
<td>Installation of first Flash Smelter (First Outokumpu Furnace)</td>
</tr>
<tr>
<td>1963</td>
<td>Solvent Extraction/Electro-winning process developed in Arizona as a means of obtaining copper from oxide ore</td>
</tr>
<tr>
<td>1970</td>
<td>NEPA (National Environment Protection Act) promulgated in the USA, signalling the beginning of formal environmental assessment procedures, which rapidly spread to other countries.</td>
</tr>
<tr>
<td>1989</td>
<td>Closure of the Bougainville Copper Mine on Bougainville Island, PNG due to civil unrest</td>
</tr>
</tbody>
</table>

Source: based on Hartman (1987)

reference, ‘Gold’ by Kettell (1982) provides a thorough history of the one metal that has captivated the imagination more than any other. Further authoritative reviews of mining history can be found in Gregory (1981), Boyns (1997) and Meyerriecks (2003).

**Mining Today**

Dramatic improvements in mining and mineral processing technologies have effected two main changes in modern mining operations, as compared with mining practices of less
than a century ago; mining now occurs at a much larger scale, and much further from population centres (see Appendix 1.2 for some examples).

The purpose of mining is to excavate from the existing surface down to the mineral deposit. Modern technologies and equipment allow excavation at a previously unknown scale, exploiting mineral deposits that would have been uneconomical with past mining technologies (Figure 1.1). Ore production rates can now reach a staggering 100,000 tons per day or more, with total excavation (ore plus waste rock) exceeding 500,000 tons per day at the world’s largest mines. As the scale of mining increases, the need for supporting infrastructure also increases. Today’s mining operations may require whole mining towns with associated infrastructure, including hospitals, air and seaports, power plants, landfill facilities, and roads.

Given the massive scale of today’s developments, a project may become the nucleus of region-wide or even national economic development. The consequences of mining at such large scale in remote areas, however, are not all favourable. In fact, few industrial endeavours generate more controversy. In the first instance, land clearing for mine access, excavation of ore, particularly in the case of open Pit mines, and provisions for waste rock and tailings, all change the landscape profoundly. Secondly, there may be community impacts which are difficult to identify and plan for in advance, including social, economic, and political changes which potentially affect the opening, operation, and closing of a mine. It is also true that benefits generated by the mine are almost never equally distributed; although many profit, large numbers may also lose out as mining processes alter the landscape, and disrupt social and economic networks.

The move to larger scale and more remote sites has been accompanied by another challenge for the mining industry, that is, to contain extraction and processing costs in the face of declining ore grades. The resulting increase in the volume of processed ore means that the cost and volume of waste per unit of metal extracted increase, potentially resulting in greater costs of environmental management as well. To date, these costs have been managed by technological advances, specifically in the development of larger, more cost-effective bulk haulage systems.

**Mining Terminology**

As in any specialized discipline, there are many terms and expressions unique to mining (for a complete glossary of mining terminology see standard references such as Trush 1968;
Gregory 1981; or www.geology.com). Most mining terms in this textbook are introduced selectively, but a few key terms are defined below.

Mining is defined as all activities related to excavating rocks, stones, or minerals that can be sold at a profit. In a more general sense it also includes the subsequent extraction of valuable metals. The extraction of valuable minerals and further refining is referred to as mineral processing, detailed in the following section. Mineral processing covers a wide range of metallurgical processes, ranging from simple gravimmetrical separation to complex high-pressure acid leaching to smelting. Primary mineral processing is commonly based on physical processes, referred to as ore beneficiation. Beneficiation is an integral part of many mining operations.

The excavation made into the Earth-crust to extract minerals is called the mine. The mined mineral itself is a naturally occurring substance, usually inorganic (coal, the most obvious exception, is an organic compound), having a definite chemical composition and distinctive physical characteristics.

Unique mining terms and expressions impose unexpected challenges in working on mining projects in countries with a relatively young mining history. Often no equivalent for a specific mining term exists in the local language, which makes the preparation of documents such as environmental impact statements challenging. It is not uncommon for English mining-specific terms, such as tailings, to be adopted in many languages and even to become part of national mining legislation (e.g. Ind. Government Regulation 19 of 1994).

### 1.2 THE PATH OF MINERALS FROM CRADLE TO GRAVE

Mining is only the first step in the minerals cycle, that is, the path of any given mineral from cradle to grave. The concept of conducting a detailed examination of the life-cycle of natural resource use, a product, or a process is relatively recent, having emerged in response to increased environmental awareness. The immediate precursors of life-cycle analysis and assessment were the global modelling studies and energy audits of the late 1960s and early 1970s, which were attempts to assess the resource cost and environmental implications of different patterns of human behaviour. Life-cycle analyses were an obvious extension, and they are now vital to the evaluation of mineral use, from mining to the manufacturing processes, the energy consumption in manufacture and use, and the amount and type of waste generated. The study of minerals cycles is instrumental in accurately assessing the total burden placed on the environment by natural resource use. A number of different terms have been coined to describe life-cycle analysis, such as Life Cycle Inventory, Life Cycle Assessment, Cradle to Grave Analysis, Eco-balancing, or Material Flow Analysis. Whichever name is used, life-cycle analysis is a potentially powerful tool, which can improve understanding of the environmental consequences of mineral use.

**Minerals Cycle**

Minerals are natural resources which are essentially non-renewable, a term applied to resources whose natural regeneration cycle is extremely long. Minerals, metal ores, fossil fuels, and soils do regenerate, but this regeneration takes thousands or millions of years. As a result, non-renewable resources are generally regarded as finite, and their consumption as ‘irreversible’, a concept underlying the minerals cycle in our economy as depicted in Figure 1.2.

Minerals are extracted, transformed into products and goods, transported to other parts of the world, recycled and, sooner or later, released back to the natural environment as waste or
The Earth is a closed material system, which means that there are firm limits on natural resource use. For some non-renewable resources including many metals and construction minerals, security of supply does not currently give cause for concern; for others, such as oil and land, availability is already a problem that is almost certain to grow. There are also limits related to the ability of the environment to act as a ‘sink’, that is, to absorb discharges and emissions of pollutants and wastes without serious damage, illustrated most recently by Al Gore’s (2006) book on anthropogenic carbon dioxide emission and its relation to global warming.

Minerals generally have a long life-cycle, and only a small fraction of the minerals put into use each year ends up in the waste stream; those that do include metals in short-life products such as packaging material (e.g. aluminium cans). Most minerals in final products are stocked within the economy for at least several years, since they are used mainly in durable consumer goods, e.g. automobiles, and infrastructure, including the capital stock of industries (e.g. machinery, equipment, and industrial buildings). Gold is an extreme case in that most of the gold that has been extracted throughout history, remains in use or in storage. Similarly, valuable gemstones are seldom discarded.

**Recycling – Extending the Life-Cycle of Minerals**

Recycling is the most common way of extending the life-cycle of minerals. It saves primary raw material inputs, and reduces the need for new mines with associated environmental impacts. Also, in many cases, processing secondary raw minerals is less environmentally
obtrusive and requires less energy than producing primary raw minerals, particularly the case with aluminium. However, mineral recycling has its own set of environmental impacts. For some minerals, high recycling rates have already been achieved (Table 1.2). In Europe, the share of the secondary fraction (the share of scrap in the total input to production/smelting) for silver, copper and lead exceeds 50% and is about 35 to 50% for steel, aluminium and zinc (EEA 2005). In the US, recycling rates in 1998 were 59% for iron and steel, 39% for aluminium, 37% for copper, and about 22% for zinc (Hudson et al. 1999).

Recycling of any commodity depends on the relative cost of recycling versus the cost of primary production. As the commodity price increases, the economics of recycling become more favourable. However, this simple relativity may be changed by government

**TABLE 1.2**
Production, Consumption, and Recycling of Metals

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Aluminium</th>
<th>Copper</th>
<th>Lead</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative total world production (in tons)</td>
<td>32 billion tons of crude steel</td>
<td>573 million</td>
<td>409 million*</td>
<td>204 million*</td>
<td>128,000 – 140,000</td>
</tr>
<tr>
<td>Recent annual world consumption (in tons)</td>
<td>837 million</td>
<td>24.9 million</td>
<td>15.1 million</td>
<td>6.2 million</td>
<td>3,948</td>
</tr>
<tr>
<td>Share of total metal consumption derived from recycled material</td>
<td>US 79%, West Europe 55%, East and SE Asia 52%, rest of world 46%</td>
<td>North America 35%, Western Europe 31%, Asia 25%, world 29%</td>
<td>Western world 35%</td>
<td>US 70%, rest of world 35%</td>
<td>Western world 35%</td>
</tr>
</tbody>
</table>

*World production from 1900–2000

Source: MMSD 2002

Because the extraction of aluminium from alumina requires an enormous amount of electrical energy, the aluminium industry initiated processes to recycle used aluminium and was one of the first industries to do so.

**CASE 1.1**
Battery Lead Recycling in Germany

In Germany, as in most countries, discarded automobile batteries constitute the main source of recycled lead. Being environmentally sensible, battery recycling seems a practical and easy solution to extending the life-cycle of lead. On the surface, considering that mining costs do not occur, producing lead from recycled batteries seems also to be a very lucrative business. Reality differs. In the early years there were no incentives for battery owners to prevent uncontrolled dumping of batteries into the environment. Once penalty and reward systems were introduced to support battery recycling, the supporting infrastructure such as means of collection and transport were lacking. Dismantling of batteries proved difficult, and generated a wide range of undesirable hazardous wastes as by products. Lead recyclers expanded into plastic recycling to reduce some of the waste streams now facing the considerable technological challenge of separating various types of plastics. During the 1990s, the lead market became increasingly flooded with primary lead produced by Eastern European mining operations at low cost, being subject to less stringent environmental laws and regulations. Ironically at the same time European governments pressed forward to reduce the use of lead, even considering the extreme step of banning its use. As this example clearly illustrates, a successful recycling scheme requires the commitment of many parties — government, consumers, and industry.
Although recycling is important, there is an upper limit to the amount of mineral that it can provide.

**Mineral Flows Vary**

While Figure 1.2 is illustrative, mineral flow through most economies differs from the global cycle. Large differences exist between countries, as developed countries make a much greater claim on raw materials than do developing countries. The 20% of the world’s population living in rich countries uses, on average, about 50% of the world’s mineral reserves. Rich countries are increasingly reliant on minerals extracted abroad. In most European countries, domestic extraction of material resources has decreased while imports have increased as a result of macro-economic restructuring, rising domestic costs of production, availability of cheaper products from abroad, removal of trade barriers, and increased use of recycled materials (EEA 2005, Figure 1.3). As global markets open further, this trend is likely to continue.

The scope for opening new mines in developed countries is also decreasing due to the public perception that mining is inherently and unavoidably damaging to the environment. As a result, increasingly large areas in developed countries are now being closed to new mineral development. This manifestation of the ‘NIMBY’ (Not In My Back Yard) syndrome immediately leads to the question: Well, if not in your back yard, then in whose? Such restrictions raise the question of how environmental and economic responsibilities, including both the responsibility for environmental damage from mining and for providing the world with the raw materials it needs, can be shared equitably. Developed countries have focused on the downstream use of minerals, and most of the ores used in developed countries are imported. Canada and the US are notable exceptions, both continuing to rank high as leading mining countries. The US and Western Europe are generally the highest minerals consumers per
capita, as shown in Figure 1.4. The contrary is found in many developing countries, where the economies often depend on primary production industries such as mining, along with agriculture, fisheries, and forestry.

Path of Minerals and Associated Environmental Impacts

The entire life-cycle of mineral resources can give rise to environmental impacts, from extraction, transportation, through use in the production and consumption of goods and services, to final disposal as waste. Each phase presents its own environmental challenges, affecting different localities. In fact, the consumption of metals and the resources used in their production exemplify the degree to which international trade flows determine the extent and location of environmental pressures. For example, iron ore mined in Western Australia may be converted to steel in Korea using coal mined in Indonesia. Korean steel plate may then be used to build a ship in Japan, which after a lifespan of say 20 years will be beached and disassembled for scrap in India or Bangladesh, with the scrap steel sold to Germany, and so on…

Extraction processes are often very damaging to landscapes. As will be discussed in subsequent chapters of this book, a number of metals, such as gold, nickel, and copper are extracted with environmentally-intrusive mining technologies, resulting in large quantities of mine wastes, potential contamination of soils, landscape destruction, and negative impacts on natural water cycles. Environmental impacts in the later stages of processing will differ, i.e. concentrating and refining crude metal ore, smelting, or forming, but all are energy-intensive activities. They all require other non-renewable resources (e.g. fossil

FIGURE 1.4
Consumption of Metals Compared with Population by Region for Selected Countries, 2000

The US and Western Europe are generally the highest minerals consumers per capita.

Source: MMSD 2002
fuels) and some may produce air-borne emissions that may contribute to global environmental challenges such as climate change, air pollution, and acidification. Environmental challenges of the use phase are determined mainly by the final product in which the minerals are embodied, and generally have little to do with the nature of the mineral itself.

The uneven distribution of mineral production and consumption raises another concern: the high and increasing consumption of scarce resources and resulting pollution, particularly in the most industrialized countries, is potentially at the expense of the rest of the world, and of generations to come.

A full study of the immediate and long-term impacts of the mineral cycle would cover many volumes. This book, however, focuses primarily on assessing environmental impacts that are related to mineral exploration, mine site development, extraction mining, and primary mineral processing – mostly in the form of milling, washing, grading, and concentrating. As noted above, these activities have increasingly shifted from the industrialized world to developing countries. Many mining operations also integrate the subsequent extraction of valuable metals, commonly referred to as mineral processing. This is often the case in gold mining, where the shipped product is commonly gold, not concentrate. Limited attention is given to discussing mineral processing and related environmental impacts, with references provided for those who desire further reading on related topics.

1.3 ORE – A NATURAL RESOURCE BLESSING?

Mines operate in a complex web of economic, environmental and social forces and are therefore inherently subject to political realities. They necessarily function within the administrative and legal infrastructure of the host country, and are also confronted with local and regional pressures from the communities most directly impacted by mining operations. A brief discussion of these political, economic, and environmental dimensions follows.

The Political Dimension of Mining

Developing country political environments vary widely, but there are two characteristics common to most, if not all: the first is some degree of international economic dependency. The dependency of countries that own mineral resources on international mining companies or, more accurately, their respective home countries as metal consumers, is an important reality of the metal market, with potential consequences for trade and diplomatic relations. The second characteristic is a two level, or ‘dual’ economic and social structure. That is, one portion of the economy resembles that of a developed country, with access to a modern transportation and communications infrastructure, and participation in a cash based, consumer oriented culture. Generally the middle and upper classes in such a society represent a relatively small portion of the total population. The second level is a much larger percentage that remains embedded in a more traditional agricultural society, with limited access to the goods and services of the modern sector. Good examples are India, China, and Indonesia, but most developing countries display some characteristics of this duality. The existing political and economic distortions of dual economies may be reinforced by large mining projects, which appear to benefit the already rich at the expense of the poor. This can lead to project focused social disruption, which can affect implementation. Exploitation of mineral wealth can also be the basis for broadly based economic development, as in Botswana and Chile, although this is atypical (World Bank 2002 a,b).
The Investment Climate
Metal mineral reserves are limited, but this does not mean that reserves will be exhausted in the near future. Exploration will go ahead following demand and price movements, and new exploration and mining technologies will allow the mining industry to exploit deposits that previously have been economically unattractive. While the location of each deposit is fixed, international mining companies can often choose between multiple deposits located in different national jurisdictions. Investors will consider not only a proven ore resource but also political, social, economic, and administrative characteristics (the ‘investment climate’) of the host country prior to committing significant investments (Case 1.2). As a consequence, countries that possess mineral reserves are in competition to attract investment dollars. The existence of superior ore bodies will not by itself attract investment.

Administrative infrastructure differs among developing countries, although some generalizations may be made. Most developing countries suffer from inadequate resources to staff and properly manage administrative organizations, and may lack a tradition of social processes based in law. To those proposing large mining projects, administration in developing countries commonly exhibits one or more of the following deficiencies:
- inefficiency;
- lack of concern for the realities of business and commerce;
- lack of transparency;
- disregard for existing laws and regulations;
- avoidance of accountability and responsibility; and not infrequently, corruption.

Legal Systems and Un-coded Legal Traditions
The legal system of a developing country, including commercial law, tends to reflect its colonial history: British common law in the case of former British colonies, the Napoleonic Codes for France, and Roman law in the case of the Netherlands. Such systems are well understood by investors and provide a degree of comfort, although the existence of a legal system does not necessarily ensure its application in all cases. Of utmost importance to prospective mining investment is “security of tenure”, the inherent right of the discoverer to develop the deposit. Development of a new mining operation requires many years of effort and substantial expenditure before there is a financial return to investors. It is therefore

**CASE 1.2**
**Mining in the Philippines**
The Philippines, being located on the ‘Pacific Ring of Fire’, is the home of many mineral enrichments, some of them well known, others yet to be discovered. While mining in the Philippines goes back for centuries, production has declined substantially since 1990, and no modern large scale mine has been developed in the past decade despite surging metal prices and booming exploration and mining activity in less prospective countries. What hinders the interest of foreign mining companies? The Philippines continues to rank high in terms of corruption. Until recently the investment law prevented foreign majority ownership. Land rights remain unclear. Past mining accidents (some involving loss of life) caused by irresponsible mining operations, fostered widespread community opposition and resistance to mining. The influential Catholic church has publicly opposed mining on many occasions. As a result, the Philippines has missed out on the investments that could provide jobs and help reduce poverty in the poorest parts of the country.
understandable that any doubt relating to security of tenure would be enough to discourage mineral exploration, let alone development. Accordingly, those countries where security of tenure is legally guaranteed are the focus of most exploration. Similarly, any attempt by governments to apply significant retrospective changes after development expenditures have been committed will cause many companies to re-direct their efforts. There is a tendency during periods of high commodity prices for countries to seek higher returns. This has led to various forms of windfall taxes or royalty increases, based purely on the perception that the company can afford to pay the additional impost. Where applied retrospectively, these imposts will certainly curtail future exploration, not only because of the effect on profits, but because they signal that the Government involved does not honour its agreements.

In contrast, social interactions at the community level, including commercial and trading relationships, are often based on un-coded legal traditions, which may be difficult for outsiders to access and understand. Mining companies tend to ignore these local traditions, which are often more important to rural communities than imposed national legal codes. Tension between local communities and mining companies may rise as a direct consequence. The Bougainville Copper and Ok Tedi mines in Papua New Guinea are good examples of what can go wrong as a result of mutual misunderstanding (Case 1.3).

**The Key Provisions of Mining Codes**

There are two apparently conflicting interests in a host country’s stance towards mining investment: the need to promote foreign direct investment in order to foster economic growth, and the need to control investment to protect national sovereignty, as well as the interests of national elites. These two interests find expression in country-specific investment laws. Laws that apply to foreign investments govern a wide range of aspects including...
taxation, property protection, labour, social welfare, and foreign exchange. Specialized legislation often complements general law, particularly for the mining industry in the form of mining codes. The provisions of most mining codes can be categorized into the following five areas (Otto 1997a,b):

- **Property and control rights.**
  With few exceptions, ownership of subsurface minerals remains with the host country's national government. Mining companies are essentially contractors who exploit mineral resources on behalf of that government. Exclusive national control of the mineral resources is common, although some governments have moved to share returns with regional or local entities, for example, the Philippines and Indonesia. Exclusive national control of mineral deposits is problematic in that local governments and host communities with traditional land rights feel disadvantaged; they bear the brunt of the development, but don’t always share the rewards. In these situations, resentment towards the central government is often channeled towards the mine operator, and environmental assessments need to be sensitive to such underlying tensions.

- **Classification of minerals.**
  Most mining laws exclude certain classes of minerals, such as gravel, salt, or uranium, from their application. The management of minerals outside the mining code falls to different agencies. While not the rule, local governments occasionally try to exploit nuances in classification and wording to impose additional taxes or levies on the mine operator (such as classifying overburden removal as rock mining).

- **Qualification of the concessionaire.**
  The qualifications of an applicant for a mining licence are established by applying a set of fitness criteria, such as financial strength, technical capability, no prior violation of national law or trust, and adequate local legal incorporation.

- **Mining licences.**
  Mining licences apply to the prospecting, exploration, and exploitation phases of mine operation. The prospecting and exploration phases are geared to encourage a rapid survey for minerals. The exploitation phase is more intensive, but covers a smaller area since concessionaires are obliged to relinquish concession areas over time. Both the prospecting and the exploration phases have imposed time limits. The production licence generally encompasses mining, processing, and marketing of the mineral. Under most mining codes a production licence is dependant upon presentation of an acceptable feasibility study and environmental impact assessment study. The production licence is limited in time, usually 10 to 20 years, although extensions are usually possible. The project is typically narrowly defined, and all codes describe sanctions for failure to comply with agreed terms and conditions.

- **Distribution of earnings.**
  Host country participation in mine project earnings takes many forms. Bonuses or agent's fees are sometimes charged at the closing of a contract. In addition to company taxes, royalties are the traditional form of payment. Duties and export taxes play a lesser role than income taxes. Import duties are normally suspended for capital investments to minimize initial investment costs. Mineral codes can also provide incentives, such as tax holidays, or accelerated depreciation. Additionally, mining code provisions may regulate payments to local landowners or local governments, or may...
be designed to encourage environmental protection, sustainable development, public
health measures, local purchasing, or local labour force content. Such provisions often
transfer substantial responsibilities for regional development to the mine investor. In
addition, some host countries create state-owned mining companies. Foreign investors
are required to enter into a joint venture with these companies to ensure effective state
participation in mineral exploitation. An understanding of national mining code pro-
visions that aim to encourage local, sustainable development and environmental pro-
tection is essential in the environmental assessment of a new mining project.

**The Economic Dimension of Mining – Who Benefits from
Mining, and Who Does Not**

Mining is first and foremost an economic activity. As in any other economic sector, min-
ing companies are in business to earn profits, a valid and necessary objective. Their chosen
sphere of operation is mining, carried out within a set of constraints put in place to sat-
tisfy the interests of various stakeholders. The first and foremost of these is the host coun-
try government, which represents the national interest, as well as elite, regional and local
powers. Mining companies will try to negotiate the form and nature of those constraints,
while host countries may try to shift additional responsibilities onto the industry. But the
main objective of mining, to earn profits, remains.

**The Concept of Resource Rent**

The classic concept of economic rent originated with David Ricardo (1962) in his theory
of land rent, and has been subsequently applied (Garnaut and Ross 1975, 1983) to min-
eral resources development overall and to mining in particular. In the case of mining,
Ricardian economic rents can be viewed as the excess of economic return on a project
above the total economic cost of the project.

In the case of natural resources, governments often transfer selected property rights to
industry, such as the right to mine or to exploit an area in exchange for some amount of
economic rent (with mining codes providing the legal vehicle to do so). These economic
rents collectively are known as ‘resource rents’, since they are derived from the utiliza-
tion of natural resources. Resource rents encompass all direct revenues derived by a nation
from a mining project. The most common forms of revenue are direct taxes (corporate
income tax, royalty tax, withholding tax, import and export taxes, excess profits tax) and
fees (registration, land, water, infrastructure use) for the use and development of the
nations’ resources (Garnaut and Ross 1975, 1983).

Two additional types of resource rents that are associated with many mining projects
are landowner compensation and national/local equity participation in resource develop-
ment projects (Clark 1994). In the latter case, often the rule rather than the exception in
the oil and gas industry, the national government, and occasionally the province, becomes
an actual partner in a project, thereby, acquiring a percentage of the profits in addition to
taxes and fees. As the equity partner is normally the national government or its agent, the
majority of revenues from profit sharing accrue to the national government, which may
affect revenue sharing with local governments.

As a general rule, albeit with some major exceptions, the majority of direct taxes accrues
to the national treasury, while the majority of the fees, and often a portion of royalties,
accrue to the local government. These results in a major disparity in revenue distribution,
since taxes which accrue to the national government, normally constitute 90 percent or
more of all revenues derived from a mining project. Hence the call by local governments in
most nations for a more equitable division of resource rents, theoretically a valid request, but one that is difficult to implement in practice.

The economic rents derived from mining may be quite high, accrue on a yearly basis (normally for the life of the development and in some cases beyond), but unfortunately too often are shared by a very small number of people.

National Economic Benefits
Host governments clearly recognize that the people and nation they represent can benefit from mining. It can contribute to the attainment of national development goals, even though it may be accompanied by ecological and social costs. Development goals include increasing gross national product, creating employment, increasing export earnings that can be redirected to national development, promoting import substitution, and facilitating administrative reforms. Mine support facilities such as seaports, airports or roads can complement existing transportation infrastructure, and contribute significantly to linking remote areas with the metropolis. MMSD (2002) argues that mining is important in 51 developing countries, accounting for 15 to 50% of exports in 30 countries, 5 to 15% of exports in a further 18, and being important domestically in three others.

It is argued, whether rightly or wrongly, that local communities too can profit from mining, even though a mining project may be a one-off opportunity for prosperity, and the mineral resource will be exhausted after exploitation. However, given the massive investment required, and the long time-span of implementation and exploitation cycles, the long-term social and environmental costs may appear insignificant and easily discounted.

The ecological and social costs typically associated with mining are not adequately regulated by market mechanisms alone. Developing countries correctly perceive the need to protect their long-term interests through extra-market controls, which are incorporated in mining policies and law, as well as contractual agreements with mine investors. Even the calculation of an optimal mine production rate is not always driven solely by economic factors, but may entail a complex mix of uncertainties.

Except during times of price depressions in the metal market, investors aim for high production rates in order to transform passive natural capital into financial capital at a maximum rate. Host country governments, however, may want to extend mine life by capping production rates, allowing time to realize regional development, while turning passive natural capital into human capital in the form of, say, a trained and skilled workforce. Thus contractual agreements may aim not only to protect a reasonable return on investment for mine investors, but also maximize the mine’s contribution to regional development. According to Carman (1979) and various economists since then, however, a more rapid exploitation of an ore deposit is better for the investor as well as the host government.

There is little dispute that mining can produce wealth. Unfortunately, natural resource extraction has not always led to economic and social development. In well-established mining economies such as Spain, Australia, Canada, US, and South Africa, mining has been of undoubted and significant benefit, although not without some long-term costs, as in the infamous Butte, Montana super-Pit (Case 13.7). However, many countries, among them some of the world’s poorest, have failed to convert major mining projects into sustained development. The mining industry is often blamed, but where does the responsibility of the industry end and the duty of government begin in ensuring favourable national outcomes from mining?

Incorporating Environment Costs into Economic Models
In a simplified linear model of the economy (Figure 1.5), the production process of mining and mineral processing results in both raw metals and built capital as outputs (Pearce
and Turner 1990). The production process itself relies on natural, human, and built capital. Natural capital consists of minerals, fossil fuels, land, topsoil, and water. These can be further divided into renewable resources such as forests, and non-renewables such as minerals. In this model the environment is simply a source of production inputs, and no allowance is made for the waste products that will be generated from all phases of both production and consumption.

A circular economy/environment model (though simplified) is more useful when it is desirable to capture the economic costs of waste streams (FEE 2003, Figure 1.5). The First Law of Thermodynamics states that matter can neither be created nor destroyed. Whatever is used up in the production process, however much modified, will eventually end up in the environment. The efficiency of the production process (predominantly a combination of cutoff grade, stripping ratio, and rate of recovery) will influence the rate of consumption of natural resources per unit of target output. Inefficient production processes will waste natural resource inputs. Inevitably, the natural environment becomes a sink for waste products in the form of waste rock, tailings, effluents, and gaseous emissions.

The major concern for efficient production is that the environment has a limit for absorbing or ‘assimilating’ waste products. Recycling waste can help and is beneficial in two ways: first, it can augment natural resources used in production and thus reduce the raw natural resources required for the same level of output; second, recycling results in reductions in waste volumes. Given technical and economic limits, even with optimal efficiency in recycling, the environment will continue to act as a waste sink. Traditional linear models neglect the externalities of environmental and social costs from waste streams; circular models integrate such externalities into production costs, thereby producing a more accurate picture of the real cost of a mining operation.
The Environmental Dimension of Mining

The most obvious environmental effect of mining is the alteration, sometimes approaching total destruction, of the natural landscape of the mine site. The removal of topsoil can lay vast areas bare for many years. The placement of barren rock (mostly overburden and tailings) creates massive structures with associated risks of failure. Alteration of natural landscape and deposits of rock place a heavy burden on the hydrosphere, especially in areas without ample water supply, as is common in many developing countries. Secondary environmental affects can also arise from induced development. Improved access to previously isolated areas, for example, may impact the region more than the mine itself. Mining roads open areas for illegal logging or hunting, and frequently for illegal mining. Uncontrolled settlements place additional strain on natural resources such as water, wild life, and forest products.

Global Benefits at Local Costs

On a global scale, it can be said that the mining industry simply responds to the demands of global society, producing the minerals needed to satisfy that demand. At the local level, broad theory becomes burdened with disruptive practicalities. It is possible for a well-planned and implemented mining project to bring sustainable social benefits to communities in the form of higher levels of education and health care, and other forms of physical and social capital. However, as previously noted, inevitably there are social costs associated with mining projects. They are frequently located in more remote, less developed regions, with little physical or social infrastructure to support industrial operations, and no prior experience with the kinds of environmental and social impacts which follow from a major mining development. Such projects impose a new economic infrastructure with social consequences that may extend well beyond the physical boundaries of the project.

Central to these social concerns is the establishment of settlement areas to support mining operations. Mining towns planned by the mine investors are immigrant settlements. As a result they may suffer from a host of social problems due to the absence of established and familiar social structures. A large number of people may be exposed to ethnic and economic class distinctions not previously encountered. Mining will attract many who expect to benefit from the project: communities or areas in the vicinity of the mining site can become gathering places for migrant workers, extended families of mine personnel, or for unemployed workers who stay after construction is completed. These people often place a strain on supporting infrastructure, which is designed only to cope with personnel directly related to the mine.

Mining may also initiate modernization of the region, which may include, among others, farming methods, transportation, and housing; such rapid change can have social consequences as a result of the destruction of older social and cultural norms. Finally, central to the assessment of social and economic issues is the fact that the mining project will eventually shut down. When this happens, the mine ceases to be a source of employment and a buyer of goods, stranding suppliers of goods and services in the vicinity of the mining operation without their main source of income.

The Less Visible but Highly Vulnerable Segments of Population

Given that the distribution of benefits and costs is often inequitable, mining companies have sometimes been caught off-guard by protests from, or on behalf of, less visible but highly vulnerable segments of the population. These may include the poor, the elderly, women, adolescents, the unemployed; also members of groups that are racially, ethnically, or culturally distinctive; and further, occupational, political, or value-based groups for whom a given community, region, or use of a biophysical environment is particularly
important. Although comprehensive social assessments might be seen as overly expensive, or simply not possible, good planning in the early stages can anticipate or prevent problems later on.

The World Bank’s International Finance Corporation’s (IFC) Performance Standard 7 recognizes that Indigenous Peoples, as social groups with identities that are distinct from dominant groups in national societies, are often among the most marginalized and vulnerable segments of the population. Their economic, social and legal status often limits their capacity to defend their interests in, and rights to, lands and natural and cultural resources, and may restrict their ability to participate in and benefit from development. They are particularly vulnerable if their lands and resources are transformed, encroached upon by outsiders, or significantly degraded. Their languages, cultures, religions, spiritual beliefs, and institutions may also be under threat. These characteristics expose Indigenous Peoples to different types of risks and severity of impacts, including loss of identity, culture, and natural resource based livelihoods, as well as exposure to impoverishment and disease (IFC 2006).

Perception of Change Differs
Changes in the physical environment may affect all living things in that environment. The human environment can also be profoundly altered in what Berger and Luckman (1966) have termed its social construction of reality, which at its simplest, refers to a community’s shared perceptions of reality, based on traditional as well as contemporary beliefs. The community of mining company executives, for example, will share a particular view of the social value of a large mining project, which will probably differ significantly from the particular view of a traditional community within the purview of a proposed mine. It is quite possible, in fact, that both communities will support it, although for different reasons.

A mining project creates opportunities for local communities, including Indigenous Peoples, to participate in and benefit from mine operations. Changes to local lifestyle can be viewed as either positive or negative, depending on one’s point of view. Some will view the move to a more money-oriented lifestyle and economy as a sign of positive development, for others, as UNCTAD (2006) observes, it is sign of a destructive erosion of the cultural fabric and heritage.

Due to the external social and environmental costs of mining, some development experts and interest groups see natural mineral resources as a curse, not a blessing. Their view of mining projects is that one cannot assume a country’s economy will automatically benefit, over the long-term, from the exploitation of its natural resources. On the contrary, they argue, countries with mining end up with the burden of long-term environmental costs without lasting benefits. The perceived discrepancy between the benefits of industrial development and the needs of environmental conservation has now become the subject of a sharp controversy between industry and protectionists, a dispute in which mining companies often find themselves in the centre.

There is no doubt that mining can cause profound environmental and social change. And it also has to be acknowledged that influential interest groups or individuals may limit the potential benefits for the broader public. That said, modern mining practices and appropriate planning when fully and properly implemented can allow not only the mitigation of the negative effects of large mine projects, but also promulgation of initiatives that contribute substantially to regional and national development. Mineral and coal deposits are a passive resource. Whether a curse or blessing will be determined by the commitment of both the host country and the mining company to equitable and sustainable development.
1.4 WHAT MAKES THE MINING INDUSTRY DIFFERENT?

Clearly the mining industry differs in significant ways from other industrial sectors. For one, mining influences the economic profile of most countries, which are either mineral producers or mineral products consumers, or in many cases both. For another, as discussed in a later section, mining has a unique risk profile. But there are other characteristics that are unique to mining. The pressure-state-impact- response model, illustrated in Figure 1.6, helps to elaborate some mining-specific characteristics (partly drawing from the excellent text by Marshall 2001).

The Drivers – Demand and Supply

The demand curve in the mining industry differs in significant ways from other sectors in that it is very long and highly variable. Demand for minerals and thus mining is as old as civilization, and probably much older, and is unlikely to change in the future, irrespective of socio-economic or technological changes. The demand for a core of basic mineral commodities such as iron, copper, gold, silver, and lead is as old as history, although the spectrum of minerals has widened as new technologies required new elements, including uranium for energy production, and silicon for computers and communications infrastructure. Demand for a specific commodity, however, fluctuates greatly with time, as do market prices. Unlike the patterns in other industrial sectors, suspension and resumption of mining activities is common in response to changing demand and price. The recent reprocessing of mine tailings in Romania to extract gold is a good example of response to a large rise in price.

Finding new economic mineral deposits to match increased demand is also difficult. Exploration often lasts five to ten years, with environmental assessment, feasibility study preparation, and ongoing stakeholder consultations leading to necessary government approvals, taking an additional two to three years.

CASE 1.4
Freeport’s Massive Copper and Gold Mine in Papua, East Indonesia

Mining the world’s richest gold and copper deposit in one of the remotest areas on Earth. The closest most people will ever get to the mining operations of Freeport-McMoRan Copper & Gold in remote Papua is a computer tour using Google Earth.

Royal Dutch Shell first found minerals in the 1930s on an expedition to the nearby Carstenz Glacier, one of the few equatorial glaciers on Earth. In 1959, Freeport Sulphur, now named Freeport-McMoRan, arrived. Systematic exploration began in the 1970s, leading to development of the Ertsberg (the Dutch word for ore mountain) open Pit mine. In 1991, the massive Grasberg deposit was discovered nearby, just as the Ertsberg deposit was depleted. The Grasberg and associated ore bodies have proven reserves of 46 million ounces of gold and about 40 m tons of copper, according to the company’s 2004 annual report.

As Freeport prospered into a company with $2.3 billion in revenues, it also became among the biggest — in some years the biggest — source of revenue for the Indonesian government. It remains so. Freeport states that it provided Indonesia with about $15 billion in direct and indirect benefits between 1992 and 2005, almost 2 percent of the country’s gross domestic product (GDP). With a daily ore production rate of well over 200,000 tons and a gold...
price over US $540 an ounce, government payments in form of dividends, royalties, and taxes amount to US $1 billion per annum (The Jakarta Post, April 20, 2006).

The Freeport mines contributed about 70% to the GDP of the Province of Papua in 2006, and close to 100% of the Timika regency in which the mine is located. The company provides additional funds for community development programmes to the amount of US $50 m per year.

The original legal agreement between Freeport and the Indonesian Government, signed in 1967, served as a model for all subsequent contract of work agreements. In spite of the enormous economic benefits, however, the mine continues to be the focus of environmental and social controversy. Constrained by unsuitable topography from developing conventional tailings disposal systems, the mine disposes of its tailings into the natural river system. The tailings are contained by a system of levees in the lowlands forming a tailings deposition area covering more than 100 km². Fine tailings are also carried into the Arafura Sea.

Many of the decisions during mine development were made by the central government without consultation with local government and local tribes. The central government still holds a 10% share in the mine, while the local government has no share. Freeport has been accused of killing local people, violating the rights of Indigenous Peoples and polluting the environment. Mining, and significant community funds resulting from the mining operation, have attracted large numbers of people, and the population of the town of Timika grew from a few thousand to more than 60,000 over less than a decade.
Construction can take one to three years depending on the size and nature of the mine. In addition, developing a mine usually requires hundreds of millions of dollars in capital investment. Unlike manufacturing, a mine does not usually have the luxury of starting small and, if things go well, expanding (Marshall 2001). To achieve the economies of scale required to generate an adequate return on investment, a modern mine must start large with associated large capital costs. There are almost always extensive upfront development costs incurred before actual ore extraction commences, e.g. to remove overburden in the case of an open Pit mine, or to provide access in the case of an underground mine. All this occurs before the mining company sees any payback of external financing or return on its investment (Figure 1.7). Finally, in recent history, the locations of demand and environmental pressures have separated. The main demand resides in the industrial countries but mining has largely moved to areas remote from the markets.

**Pressures from Mineral Extraction**

Pressures on the environment from mineral extraction, mine waste and related emissions have increased because: (1) mining has generally moved from small underground to large surface mining, and (2) the number of mines has increased. Increased amounts of extracted minerals and waste rock, and the liberation of elements such as toxic metals and sulphur have increased global pollutant flows and hence environmental pressures. In terms of emissions, the mining industry is not unlike other industries, but as mining extracts non-renewable resources, easily accessible mineral reserves diminish over time, consequently mining projects often last only ten to twenty years, although occasionally longer. However, it
is important to note that pollution problems are not always related to the extracted minerals and waste, but to altered physical-chemical conditions at the mine site. Also, the area of interest to miners, that is, the subsurface, can only be sampled sparsely and accordingly is always subject to a high degree of uncertainty.

Another characteristic of mining is that the location of environmental pressure is confined, in the main, to the area of mineral deposits. This means that mining cannot follow and utilize existing infrastructure, but must bring infrastructure and other (traditionally heavy) industry to its location. This results in the creation of secondary pressures or adverse effects, especially in the case of mine closure. Industrial and other supporting infrastructure, as well as mine related settlements suddenly become redundant, giving rise to further socio-economic pressures. However, the financial and operational responsibilities of mine owners continue after the mined resource is exhausted (Figure 1.7). The process of mine closure can last up to two years, while rehabilitation of the mine site can continue for another four years or more, with the longer periods being particularly applicable to open pit mines. Mining company responsibilities may continue even longer when persistent problems, such as neutralization of acid rock drainage, require long-term management.

**Mining and the State of Environment**

Economically valuable mineral deposits do not necessarily occur below low value surface environments, so that mines are sometimes located in or near ecological reserves and protected areas. They may also be found in conjunction with areas of geologically determined high natural background values or ‘natural pollutants’ that are associated with mineralized deposits. This means that often the terrestrial environment is already polluted before mining commences, which is, in fact, a useful tool for geochemical mineral exploration. Natural background cannot be remediates to meet limits defined by law. Nevertheless, the state of the environment over mineral deposits and certain geological formations can pose regional scale risk to human and ecosystem health. However, actual risks to health from such pre-existing conditions depend on many factors such as soil organic matter, metal speciation, pH, etc. Additionally, a given site may already be affected by regionally...
dispersed pollution from historic mining activities. Such pollution makes it difficult to separate given background from pollutants generated by recent human mining activity.

**Impacts are Complex and Vary Widely**

Mining impacts are many and varied, as discussed in foregoing sections, but tend to be local. However, not all impacts are confined to the immediate vicinity of a mine; regional impacts are commonly related to air pollution (dust, smelter emissions), ground water pollution, naturally elevated background levels, and pollution of down stream water bodies and flood plains. Pollution impacts are often long-term, but also can be delayed, as in long-term acid rock drainage, becoming in effect chemical ‘time bombs’. However, the socio-economic impacts of mining and mine closure in the host country are often of a higher significance than the physical and ecological environmental effects, particularly in the short term and in the political sphere.

**Society’s Response**

In terms of response, perhaps the most important reality of mining is that ‘zero impact’ is essentially impossible. However, societies can respond to mining and mining induced changes in a variety of ways ([Figure 1.6](#)). One is the reduction of demand for minerals through substitution of traditional materials with synthetic ones (recognizing of course that production of synthetic materials involves its own environmental impacts). Demand can be further reduced by product recycling; by reworking of mineral wastes as secondary resources; and by use of material efficient technologies. Although necessarily long-term, ultimately such measures can relieve pressure on the environment.

Mine wastes and emissions can be decreased by improved management, particularly in conjunction with new technology. Overall, the state of the environment can be improved by appropriate environmental management. Environmental Impact Assessment and Risk Assessment studies of mine sites have long been a requirement in identifying and ameliorating environmental degradation and in preparing response strategies for possible accidents. Introduction of environmental management systems as an integral element of project design in all mining projects can further decrease potential impacts, and the ‘design for closure’ approach can minimize impacts after closure.

**1.5 THE UNIQUE RISK PROFILE OF MINING**

Mining has a unique risk profile, not only in relation to the environment or applied technology, but financially, politically, and legally. In a legal context, an operator’s rights to a mining project (and its ability to generate cash flow and profits) depend on a series of contracts and interpretations of applicable mining laws as well as general law. Political instability may encourage reinterpretation of contracts and legal requirements, or foster social disruptions focused on mining projects. The international economic climate may change, driving costs up and returns down. Even if global economic conditions are favourable for new mining projects, risks remain and a comprehensive risk management plan is essential to a profitable outcome. Table 1.3 lists the main risks to successful implementation according to the level on which they occur: country level, sector level, and project/enterprise level. Lay (2006) and