Vast areas of the world have been laid waste by destructive human activities: poor agricultural practices, industrial pollution, warfare, etc. (WCED 1987; Smit 1993; Edwards 1994). It has been estimated that at present there are approximately 2600 million ha of degraded land (approximately the combined size of Canada and the United States) and that this number increases by 5–7 million ha each year (Wall 1992). Mining and smelting have contributed heavily to these losses, being responsible for more than 20 million ha of some of the most severely damaged areas (Moore and Lioko 1990). These losses of productive lands and waters and the interferences with the health of natural systems on which they depend are continuing to occur at the same time that the need for ecological services (i.e., food, water, fibers, natural medicines, microbial decomposition of waste products, etc.) accelerates because of increasing individual demands for resources and a world human population that doubles approximately every 40 years (Ehrlich and Ehrlich 1991). For example, in China, a country expected to contain 1.25 billion people by year 2000, approximately 40 million ha of arable land (30–40% of the national total) has been lost in the past 50 years by soil erosion, urbanization, transportation, and industrial pollution (Smit 1993).

There is no consensus on what the ultimate carrying capacity of the earth will prove to be, but there is no doubt that accelerated growth cannot be sustained on a shrinking resource base (Gore 1992; Houghton 1994; Woodwell 1994). Losing vast areas of productive land is intolerable under such a strain on global resources.

Changing values in society create a new ethical environment in which companies must operate (Potter 1988; Dunlap and Scate 1991). Society is now less willing to tolerate ecologically unwise companies that suggest that what is good for the company is good for society because it generates wealth through jobs and useful products. Other values (essential ecological services, recreational activities, animal rights, protection of biodiversity, etc.) in land use choices have now begun to take precedence over the idea of “production at lowest possible cost.” These values have become so significant that some industrial developments are stopped.

1 This paper was prepared by the synthesis group that consisted of representatives of government resource management and environmental agencies, the mining industry, municipal government staff, and the university. The group reviewed all previous chapters from the Sudbury case history before preparing this discussion paper.
by them. For example the construction of the
Windy Craggy mine in British Columbia was
recently restarted because of environmental
concerns, even though more than $40 million
had been spent by the company developing
the site.

**Sudbury Case History**

The extensive destruction of land and water
by industrial emissions from Sudbury repre-
sents one of the best-known environmental
impacts in North America. These damages
were not intentional; in fact, it can be ar-
gued that over the years "best technologies"
were used to prevent their occurrence. But,
unfortunately, severe damages did occur.
A landscape that once supported a rich variety
of natural resources—forests, fish, wildlife,
etc.—was reduced to a barren wasteland in a
few decades of mining and smelting.

There is no particular magic or uniqueness in
the solutions to environmental damages in Sud-
bury. The same solutions apply everywhere:
(1) reduce the contamination and (2) repair the
damage. Progress on these so easily stated but
difficult to implement solutions has been the
subject of this book. In this final chapter, we ask
ourselves what we have learned from the Sud-
bury experience that will maintain and encour-
age further restoration efforts in this area and
whether there are some lessons of general ap-
lication that others might take from Sudbury
when working toward "sustainable ecosystem"
elsewhere.

**Irrony of the Term Sustainable**

It may seem ironic to use a case history of
a hard-rock mining area to discuss ecosystem
"sustainability." High quality ore deposits are
a nonrenewable resource that can be rapidly de-
pleted with current technologies. Mining has
traditionally been a transient industry involv-
ing short-term use of land without regard to
other future uses of that land. The presence of

**Ingredients for Progress**

Mining was essential to the environmental
improvements that occurred in Sudbury. The
recognition that change was needed was to a
large degree simply part of a broad societal
change in attitudes that began in the late 1960s
and early 1970s and rose rapidly through the
1980s. The enormous investments in time and
money needed to initiate environmental
cleanup in Sudbury would not have happened earlier.

Once initiated, what factors shaped or encouraged the particular directions that the Sudbury restoration efforts took?

1. Government pollution control legislation was the essential stimulus for industrial cleanup, but regulations were applied with "patience," giving the industries sufficient time and freedom to develop optimal strategies for pollution control.

2. The abatement programs occurred during a prosperous time for the mining industry (e.g., more than a billion dollars have been spent in Sudbury on emissions control and land and water treatments in the past 30 years), and government agencies were able to support expensive programs for environmental nonpointing, land reclamation, research, etc. A great many other industries and countries would not have had these financial resources.

3. Economic benefits for the companies were obtained through the technology developments designed to meet environmental protection requirements (e.g., energy efficiency, worker productivity, marketable products from former waste).

4. Effective partnerships developed between industry, government, academia, and the public to design and implement restoration projects. Again, timing was important. People and groups were ready to work together and synergistic benefits from cooperation were soon obvious.

5. A minimal treatment approach for damaged lands proved effective, demonstrating that substantial gains could be made by assisting and working with nature—assisting the healing process—rather than striving for an overly designed and manipulated landscape (earlier engineered solutions). This cost-effective ecological approach emphasized the use and re-establishment of mainly native species.

6. Restoration projects did not wait for perfect solutions but focused on achievable goals by remaining flexible and making use of a variety of funding and staffing opportunities. Projects were supported and enriched through expert opinion and accumulated practical experience.

7. Efforts were made to involve the public in the restoration programs through direct participation and education. Volunteers are now recognized as essential to the continuation of the program. An informed and involved public is also needed to direct political actions through their elected representatives.
Public Pressure and Legislation

Public pressure was the incentive that forced governments to demand reductions in atmospheric emissions from industries such as the Sudbury smelters. The early advances in environmental control were largely driven by the concerns of local residents about poor air quality. However, by the 1980s widespread concern about “acid rain” created an enormous lobbying effort for environmental improvements (Fig. 26.2). Acid rain was probably the first regional, if not global, environmental problem around which people rallied and demanded government action. Public interest in environmental issues tends to vary with social and economic conditions in the country (Dunlap and Scarcie 1991), but public pressure on governments will, no doubt, continue to force change. Indeed, Sudbury industries will probably be faced with more stringent regulations in the future, for although they have achieved nearly 90% reductions in sulfur dioxide, they remain as very large emissions sources (Table 26.1), and the worldwide problem of acidification has not gone away (Jeffries and Lam 1993; Galloway et al. 1994).
<table>
<thead>
<tr>
<th>Name of plant</th>
<th>Type</th>
<th>Location</th>
<th>Emission (tonnes sulfur)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NorthPark (1980s)</td>
<td>Smelter</td>
<td>Russia</td>
<td>1,590,000</td>
</tr>
<tr>
<td>Inco (1960)</td>
<td>Smelter</td>
<td>Canada</td>
<td>1,000,000</td>
</tr>
<tr>
<td>1. Martinia</td>
<td>Power station</td>
<td>Bulgaria</td>
<td>350,000</td>
</tr>
<tr>
<td>2. Puente Garcia Rodrigues</td>
<td>Power station</td>
<td>Spain</td>
<td>270,000</td>
</tr>
<tr>
<td>3. Janschwalde</td>
<td>Power station</td>
<td>Germany</td>
<td>215,000</td>
</tr>
<tr>
<td>4. Montegoriskii</td>
<td>Smelter</td>
<td>Rusia</td>
<td>212,000</td>
</tr>
<tr>
<td>5. Nikel</td>
<td>Smelter</td>
<td>Rusia</td>
<td>211,000</td>
</tr>
<tr>
<td>Falconbridge (1960s)</td>
<td>Smelter</td>
<td>Canada</td>
<td>190,000</td>
</tr>
<tr>
<td>6. Selma</td>
<td>Power station</td>
<td>Russia</td>
<td>184,000</td>
</tr>
<tr>
<td>7. Teruel</td>
<td>Power station</td>
<td>Spain</td>
<td>183,000</td>
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<tr>
<td>8. Turceni</td>
<td>Power station</td>
<td>Romania</td>
<td>183,000</td>
</tr>
<tr>
<td>9. Eibisit</td>
<td>Power station</td>
<td>Turkey</td>
<td>180,000</td>
</tr>
<tr>
<td>10. Bicentenario</td>
<td>Power station</td>
<td>Poland</td>
<td>171,000</td>
</tr>
<tr>
<td>11. Abo-Eibisit</td>
<td>Power station</td>
<td>Turkey</td>
<td>145,000</td>
</tr>
<tr>
<td>12. Soria</td>
<td>Power station</td>
<td>Turkey</td>
<td>143,000</td>
</tr>
<tr>
<td>13. Prunetov</td>
<td>Power station</td>
<td>Czech Republic</td>
<td>137,000</td>
</tr>
<tr>
<td>Inco (1990s)</td>
<td>Smelter</td>
<td>United Kingdom</td>
<td>133,000</td>
</tr>
<tr>
<td>14. Drez</td>
<td>Power station</td>
<td>Spain</td>
<td>132,000</td>
</tr>
<tr>
<td>15. Zaporizhe</td>
<td>Power station</td>
<td>Ukraine</td>
<td>129,000</td>
</tr>
<tr>
<td>16. Weagen</td>
<td>Power station</td>
<td>Turkey</td>
<td>127,000</td>
</tr>
<tr>
<td>17. Bleckberg</td>
<td>Power station</td>
<td>Germany</td>
<td>126,000</td>
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<tr>
<td>18. Moldavia</td>
<td>Power station</td>
<td>Moldavia</td>
<td>122,000</td>
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<tr>
<td>19. Kremnic</td>
<td>Power station</td>
<td>Turkey</td>
<td>118,000</td>
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<tr>
<td>20. Lunenroth</td>
<td>Power station</td>
<td>Belarus</td>
<td>116,000</td>
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<tr>
<td>21. Norwecherkass</td>
<td>Power station</td>
<td>Rusia</td>
<td>116,000</td>
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<tr>
<td>22. Westray</td>
<td>Power station</td>
<td>Turkey</td>
<td>113,000</td>
</tr>
<tr>
<td>23. Rydvan</td>
<td>Power station</td>
<td>Russia</td>
<td>110,000</td>
</tr>
<tr>
<td>24. Hagengenrider</td>
<td>Power station</td>
<td>Germany</td>
<td>110,000</td>
</tr>
<tr>
<td>25. Terow</td>
<td>Power station</td>
<td>Poland</td>
<td>103,000</td>
</tr>
<tr>
<td>Falconbridge (1990s)</td>
<td>Smelter</td>
<td>Canada</td>
<td>29,000</td>
</tr>
</tbody>
</table>


**Maximum allowable emissions for 1994.**

Public pressure also acts directly on polluting companies. A negative public image—not only damages social and economic confidence in that company and industry, it runs the risk of inducing boycotts by consumers and investors (e.g., European attitudes toward North American harvest of "old growth" forests or fur bearers). Public attitudes and the reality of past-destructive activities also affects the ability of a company to extract and maintain high-quality staff. In the past, environmental concerns appeared to be less of an issue when workers sought places of employment. They simply went where the jobs were. However, now employees are often very concerned about the quality of their environment, and if given a choice would not raise a family in a "dirty" town or work for a "dirty" company. Under these socioeconomic pressures, it is therefore important for each mining company to not only actively participate in pollution prevention and restoration efforts but also to be perceived to be making progress in these areas, b-ak as a company and as part of a larger industry.
Economic Benefits and Costs

There are now many economic incentives for pollution control. In this case study, the contaminants that were responsible for environmental damage (i.e., copper, nickel, sulfates) are actually the products (or had the potential to be, in the case of sulfur) that the company produced. Preventing their loss is of obvious economic benefit (see input management discussion by Odum [1989]). Once forced to invest in abatement programs and to conduct strategic planning (i.e., beginning when the ice is still in the ground, rather than trying to deal with a pollutant that is already in the smokestack), considerable economic efficiencies, particularly in energy consumption, were achieved. These were of direct benefit to the companies. The reduced fossil fuel use also lowers emissions of greenhouse gases, another global environmental problem. Interestingly, this energy efficiency gain was the same one that followed from technology development conducted in the 1970s by Japanese car companies to meet stringent U.S. automobile emission standards (Nishimura 1989). Not only did the Japanese meet the pollution standards, but they achieved energy efficiency in the new engines that greatly increased consumer demand for their product.

The technological developments that were needed to meet the reduced sulfur dioxide limits were part of an overall modernization program that was necessary even without the environmental legislation. The legislation may have speeded up the process, but improvements in the smelters and in the overall efficiency of the industrial operations had to occur if the local mining companies were to remain competitive and survive in the world market place. In fact, the companies in this case did not use standard pollution control technologies (e.g., scrubbers) to meet their emission abatement requirements. They achieved these requirements by reorganizing their entire operation as part of the larger modernization program.

Unfortunately, a frequent consequence of modernization of industries is the loss of jobs. In the past 20 years, the number of workers at the mines and mills of Sudbury has been reduced by more than 50%, while production of nickel has remained largely unaffected. The socioeconomic impacts on the community from such displacement of workers has at times been very severe. An aggressive community-based economic diversification and job creation program and considerable federal and provincial government support have cushioned many of the adverse effects of workforce reductions. However, many of the changes, both environmental and economic, have been very positive for the region (expanding tourism, government jobs, new industries, etc.). No adequate socio-economic study has been done to access the net effect of these changes. Such studies are needed (Costanza 1991).

Although there were opportunities to gain economic benefits and improve the workplace environment within the industrial complex, solving the problem of a severely damaged external landscape is a different matter. Healing damaged ecosystems will not doubt prove to be a very expensive process, perhaps far more expensive than the costs of construction of facilities that caused the damage (Cairns 1993). Mining companies in North America and elsewhere are now forced through legislation to be financially responsible for environmental problems created by their operations and required to return mining and processing sites to a "rehabilitated state" before leaving an area. This responsibility greatly increases the cost of doing business (approaching true cost accounting for the cost of extracting resources) and requires the development and application of much new science and technology. However, one of the many societal benefits from this new legislation is that restoration work will generate many jobs. These jobs may compensate for some of the jobs lost during modernization of industries (Renner 1992).

Role of Partnership in Restoration

If one had to choose a single reason for the achievements in Sudbury honored at the UN conference in Brazil, it would be the cooperation and partnerships that developed to assist
restoration in this area. Partnerships did not develop through the policies of government agencies or industries. They occurred because government scientists, resource managers, university professors, municipal planners and staff, and a variety of industry personnel took the initiative and decided to collaborate and begin the restoration efforts. The enormity of the problem and the multidisciplinary nature of any potential solution demanded cooperation. The authority of government regulations still existed to drive the process, but time and expertise were not wasted on assigning blame.

It is difficult to assess why some partnerships succeed while others fail. Certainly, in our experience with cooperative projects success is largely dependent on the quality and commitment of individual people involved. A few dedicated individuals can make a great deal of positive difference even when faced with severe environmental damages. Other guiding principles of successful partnerships were that they

1. begin with and continually enhance understanding of each of the partners’ needs
2. consider that each discipline/stakeholder has something positive to contribute
3. require frequent and effective communication
4. function under the belief that cooperation can achieve more quickly and can attain larger goals than would result from the sum of individual efforts
5. remain flexible enough to seize opportunities (sources of funding, participation of volunteers, etc.)
6. measure even small progress
7. celebrate success (awards, certificates, media attention)

**Role and Opportunities for Science—Restoration Ecology**

This book began with a quote by A.D. Bradshaw that restoration research was the "acid test" of our understanding of how natural eco-systems function. Restoration projects represent unique and important opportunities to conduct research that will contribute in both basic and applied areas of ecology (Watson and Richardson 1972; Bradshaw 1983, 1993; Jordan et al. 1987). Such opportunities should not be missed. Authors in this volume have described some of the many research needs and questions that still exist in the Sudbury area. Several of these are very broad needs (e.g., rates and processes of biological recovery, chemistry and biology of degraded soils, socioeconomic of restoration), similar to some of the high-priority research items identified by the Ecological Society of America in support of its global sustainable biosphere initiative (Lubchenco et al. 1991).

There is a great need for more science in the field of restoration ecology. Far too little study has been conducted, and many industrially damaged areas could benefit from the published results of rigorous research programs in this field (Bradshaw 1993). Our experience indicates that it is easy to underestimate the need for proper scientific methods in this area of research.

Industrially damaged ecosystems such as Sudbury are the important "natural laboratories" where restoration ecology research must be conducted. An essential aspect of the design of any research work in this area is the need for controls and reference sites. Change in treated areas can only be realistically assessed against the standard of results from more pristine sites. In the same sense, some sites within the damaged area of Sudbury should be left untreated, both to illustrate to the public how far we have come but also for purely scientific reasons, to study natural recovery. A damaged area "reserve" may also serve as a reminder about what is "just over the next hill," so that the buffer strips of trees along the highways will not prove to be a facade but simply a beginning.

A frustrating problem with ecological studies is that scientific understanding usually requires considerable time to develop. However, resource managers and administrators of large-scale restoration programs frequently cannot wait for perfect answers, and projects
must often move ahead with the "best available information." Here, an experienced research scientist can make a substantial contribution by giving time and expert opinion to assist in restoration efforts, but time and funding must also be provided so at least measure change as a function of the applied restoration treatment. If we wish to improve treatment procedures, it is important that we carefully monitor environmental and ecological changes, and rigorously attempt to determine what caused these changes to occur.

Norton (1992) considered the participation of traditionally cautious and conservative research scientists in providing "expert opinion" as an essential part of a new paradigm in ecosystem management. Another aspect of this change, which we think deserves to be included in the use of the term paradigm, is the increasing involvement of industry in support of environmental research. Industry must take a larger and more active direct role in science development in the field of restoration ecology, especially now in North America, when government support for research is dwindling under difficult financial constraints.

From "Environmental Policies" to "Environmental Ethics"

The assumption of responsibility by industry for environmental damages, the increased participation of industry in science development and in large-scale restoration programs, the open exchange of information by industry with government regulators and the public, and the importance of public presentation of environmental assessment findings before development of new sites (e.g., Thayer Lindsley Mine proposal by Falconbridge Limited in 1993) are some of the evidence that profound changes are occurring in how business is conducted by many companies. It is conceivable that in the future many industries will actively participate in policy and even legislative developments for environmental protection. In fact, some companies have already made commitments to achieve standards that exceed legislative requirements and to include environmental-protection elements not considered by legislators (e.g., some recent initiatives by Shell Oil of Canada).

Certainly, public relations and economic pressures are important incentives for the development of corporate environmental policies. However, one should not dismiss the idea that a corporate "environmental ethic" (i.e., "that it is the right thing to do"), is also emerging. The personal commitment of individual executives (Allten 1991; see Foreword to Section II) and business practices such as the use of western environmental standards by companies setting up plants in developing countries without strong environmental regulations suggest that motives for change are not all profit-oriented. A cynic could easily dismiss these signals, but it is indisputable that such a change in attitude is needed to deal with the enormous environmental problems we face.

Steps toward Sustainable Ecosystems

We do not want to be labeled as naive "enthusiasts" who do not recognize the enormous global challenges we face (Hardin 1993); but this case history does provide many points for optimism and several suggestions for moving toward the goal of sustainable ecosystems. We got into this mess by adopting attitudes and actions that suggested that humans were not part of the global ecosystem, that resources were limitless, and that when ecosystems were damaged or eroded, we could simply move on. Now we know that some ideas were wrong. Humans are a part of nature, an increasingly large part (40% of net primary productivity of the land is in human enterprises [Ehrlich and Ehrlich 1991]), limits are rapidly being reached, and the "nobody" have nowhere else to go.

Environmental improvements can occur rapidly if people rethink and plan for the long-term future (NRC 1992). Hundreds of pieces of environmental legislation have been established within the past 25 years, and there are many dramatic cases of environmental im-
References


