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From Restoration to Sustainable Ecosystems[1]

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Vast areas of the world have been laid waste by destructive human activities: poor agricultural practices, industrial pollution, warfare, etc. (WCED 1987; Smil 1993; Edwards 1994). It has been estimated that at present there are approximately 2000 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 (Wali 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 Luoma 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 (Smil 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 Scarce 1991). Society is now less willing to tolerate egotistical 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 stopped 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 represents one of the best-known environmental impacts in North America. These damages were not intentional; in fact, it can be argued 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 Sudbury. 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 Sudbury experience that will maintain and encourage further restoration efforts in this area and whether there are some lessons of general application that others might take from Sudbury when working toward "sustainable ecosystems" elsewhere.

Irony 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 depleted with current technologies. Mining has traditionally been a transient industry involving short-term use of land without regard to other future uses of that land. The presence of vast areas of derelict lands is the legacy of mining in most countries (Moore and Luoma 1990; Young 1992). However, in the same way that people cannot isolate themselves from the natural world that provides the elements of life, so too a mining industry or mining town cannot separate itself from the lives of its workers or the life of the planet. For example, stack emissions from Sudbury smelters make substantial contributions to the long-range transport of contaminants, but the Sudbury area also receives pollution from other areas. In a global context, it will do little good if the Sudbury area is cleaned up at great expense, but the rest of the world does not act in a similar manner.

It is important for the reader to remember that with the Sudbury case history we are discussing restorative change at a very early stage. As any recent visitor will attest, the Sudbury region is still badly damaged—only approximately 30% of the barren land has received remedial treatment (Fig. 26.1); natural recovery under emission controls is just beginning; and there is considerable uncertainty about the effectiveness of the remedial treatments or adequacy of the legislated control orders. It will be many decades, perhaps centuries (Croker and Major 1955), before these ecosystems can be healed (toxic metals return to background levels, stable podzolic soil structure re-established, insect epidemics under natural controls, diversity of biological communities re-established, etc.). However, the direction of environmental change is positive, and this will be our cautious focus for the remainder of this chapter.

Ingredients for Progress

Timing 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 attitude 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

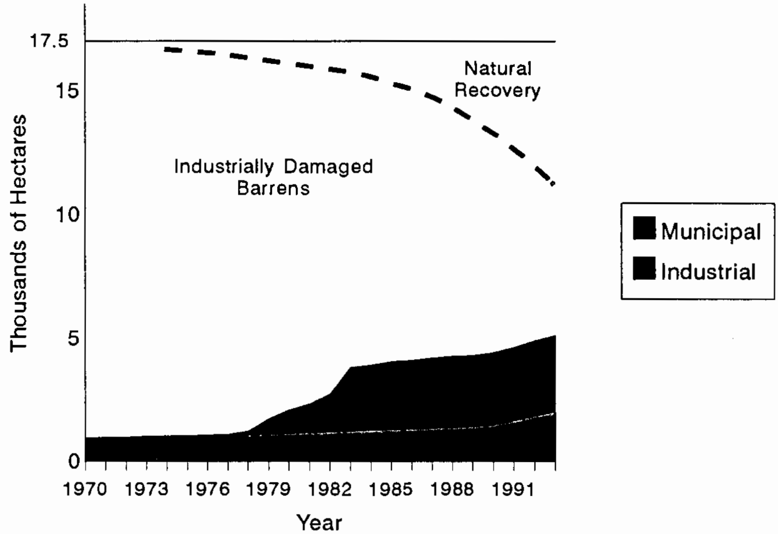

FIGURE 26.1. Changes in the extent of industrial barrens in the Sudbury area as a result of natural recolonization by plants after emission reductions in the early 1970s, and through revegetation efforts of municipal and industrial land reclamation programs. In neither the natural recovery areas nor the treated areas is restoration "complete"; the shrinkage in the barren area simply implies that a plant cover has been reestablished.

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 monitoring, 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.

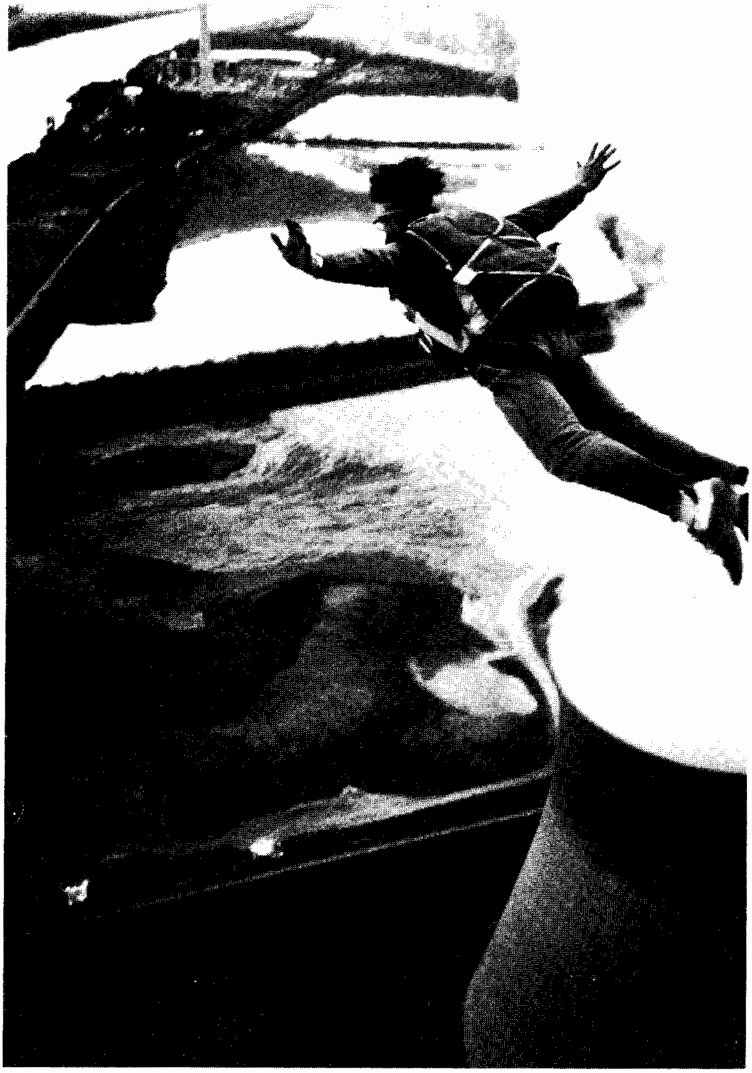

FIGURE 26.2. Environmental activist jumps off smokestack at Gavin power plant near Gallipolis, Ohio in October 1984 to protest acid-causing emissions. (Photo by Greenpeace.)

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 Scarce 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 26.1. Current and Historical (Highest Year) Sulfur Emissions from Inco and Falconbridge Smelters in Comparison with Current (1990s) Levels for the 25 Largest Emitters of Sulfur in Europe.[a] Estimated Emissions from Noril'sk in Eastern Russia Are Also Included[b]

Name of plant	Type	Location	Emission ([redacted]tonnes sulfur)
Noril'sk (late 1980s)	Smelter	Russia	1,150,000
Inco (1960)	**Smelter**	**Canada**	**1,000,000**
1. Marista	Power station	Bulgaria	350,000
2. Puentes Garcia Rodriguez	Power station	Spain	271,000
3. Jänschwalde	Power station	Germany	215,000
4. Montsegorsk	Smelter	Russia	212,000
5. Nikel	Smelter	Russia	211,000
Falconbridge (1968)	**Smelter**	**Canada**	**190,000**
6. Reftinsk	Power station	Russia	184,000
7. Teruel	Power station	Spain	183,000
8. Turceni	Power station	Romania	183,000
9. Elbistan	Power station	Turkey	180,000
10. Belchatow	Power station	Poland	171,000
11. Afsin-Elbistan	Power station	Turkey	145,000
12. Soma	Power station	Turkey	143,000
13. Prunerov	Power station	Czech Republic	137,000
Inco (1994)[c]	**Smelter**	**Canada**	**133,000**
14. Drax	Power station	United Kingdom	132,000
15. Zaporzhe	Power station	Ukraine	129,000
16. Yatagan	Power station	Turkey	127,000
17. Boxberg	Power station	Germany	126,000
18. Moldavia	Power station	Moldavia	122,000
19. Kemerkoy	Power station	Turkey	118,000
20. Lukomyl	Power station	Belarus	116,000
21. Novocherkassk	Power station	Russia	116,000
22. Yenikoy	Power station	Turkey	113,000
23. Ryazan	Power station	Russia	110,000
24. Hagenwerder	Power station	Germany	110,000
25. Turow	Power station	Poland	103,000
Falconbridge (1993)	**Smelter**	**Canada**	**29,000**

[a]From report by M. Barrett and R. Protheroc, summarized by Agren (1994).
[b]Ehrensvard (1993).
[c]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 attract 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, both 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, sulfur) are actually the products (or had the potential to be, in the case of sulfur) that the companies market. 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 ore 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 socioeconomic 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 no 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 ecosystems 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, socioeconomics 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 to 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 supporting 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 (Aitken 1991; see Foreword to Section E) 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 soiled, we could simply move on. Now we know that these 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 "nomads" 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 improvement (e.g., Lake Erie, Thames River, Singapore, Sudbury). Environmental consciousness in is now well established in a great many people, including some important politicians and corporate executives. There are also encouraging signs that cooperation rather than confrontation is gaining momentum on the environmental front. However, time to begin restoration and recovery of damaged ecosystems cannot be wasted.

This book about Sudbury was originally designed to contribute knowledge to the global goal of being able to protect, restore (Bratton 1992), and maintain healthy sustainable ecosystems (WCED 1987; Turner 1988). However, as Sudbury residents, we have probably learned the most from this exercise. It is now clear that although substantial gains have been made, we still have a difficult job ahead of us for solving our own local environmental problems. In addition, we realize that few countries will ever have the same financial resources to conduct such a large-scale restoration program. However, this fact should not discourage others from beginning restoration work. Our land reclamation program began very modestly with very little money and mainly with the assistance of volunteers, demonstrating that great progress can be made from humble beginnings.

Finally, although people should not be discouraged by the challenge of restoration, the principal lesson from our work is that preventing such damage from occurring in the first place is surely the more sensible course of action.

Clever people know how to solve problems.
Wise people know how to avoid them.
Albert Einstein

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