Environmental Technology: On the Concept and Practice of Sustainable Design

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There will always be one more river. The journey goes on forever on our little living ship of stone and soil and water and vapor, this delicate planet circling round the sun which humankind call Earth.[1]

- Edward Abbey

TECHNOLOGY AND SUSTAINABLE DESIGN

During the past several years, the topic of sustainability has entered the mainstream architectural dialogue. Although the architectural profession has moved forward in the development of sustainable theories, principles, and strategies, many architects, designers, and educators are struggling to determine how best to address these issues. As Richard Crowther states in *Ecologic Architecture*, "Actions speak most loudly of our ecological beliefs.[2] Despite tremendous progress, it is still difficult to find buildings which embody ecological principles and maintain design integrity. Many sustainable concepts remain elusive given the state of professional knowledge.

The role and potential of technology is central to the discussion of sustainable design. In *Regenerative Design for Sustainable Development*, John Tillman Lyle provides one point of view on the implications of technology, "In the 20th century it has become a general assumption that technology is indeed out of control, and that it is in large measure responsible for the social deterioration...and general malaise that plague our society."[3] He goes on to explain the instrumental role of technology in sustainable design (such as biological waste systems, passive heating, and passive cooling), "...within a relatively short period of time, the world will have to move from a simple, highly mechanized technological base to one of great complexity, rooted in natural processes."[4] Others see great potential in applying innovations developed by high-tech industries. According to Michael Davies of Richard Rogers Architects, "We are now in the middle of a second industrial revolution. We have moved from the valve to the computer. We have moved from the mechanical age to that of the solid state. An enormous revolution has happened which has changed the world and its potential. Our built environment will be affected by this revolution and we must be prepared to take positive advantage of the new technologies for the improvements of our buildings, our environment, and our lifestyle."[5] Whether the architectural profession looks toward low- or high-tech solutions, or some combination of both, technology will play an integral role in the development of a sustainable future.

Though technology can play a critical role in moving the profession forward in sustainable design; the performance of sustainable technology can differ from the design intent. New technological innovations must be implemented, yet their capabilities and limitations also need to be acknowledged. Lessons may be learned by studying projects which have integrated new systems and technologies and by assessing the level to which goals of sustainability have been achieved. The paper will investigate the role of technology in moving the profession toward the realization of sustainable design. The Boyne River Ecology Center will be used as a case study to investigate this issue and to address the relationship and the distinction between the concept and the practice of sustainable design.

BOYNE RIVER ECOLOGY CENTRE

The Boyne River Ecology Centre is a small educational

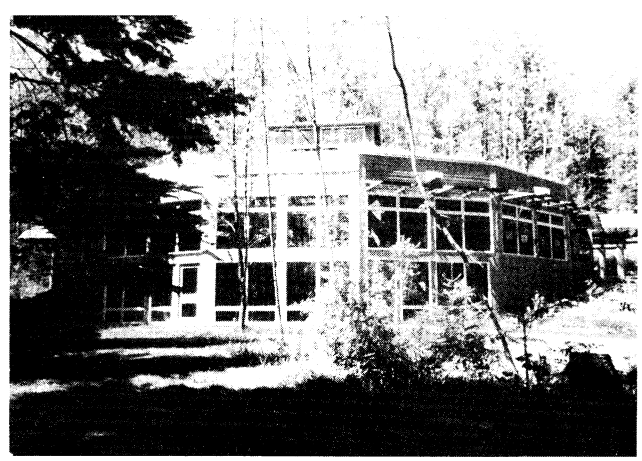

Fig. 1. South Facade, Boyne River Ecology Centre

facility which addresses sustainability on many levels - ranging from response to the existing site and ecology, through building organization and massing, to selection of materials, health considerations, and technological innovations. However, successful operation of the Centre is, to a great extent, dependent on technology. The scope of this discussion will be limited to the primary technological strategies which are essential to the ecological conception of the facility. The project illustrates the distinctions between our visions and dreams of a sustainable future and the current technological capabilities, opportunities, and limitations of the emerging practice of sustainable design.

In June 1993, *Architecture* featured an article on the Boyne River Ecology Centre (designed by Doug Pollard of Toronto, Ontario) in its annual issue on the environment. Vernon Mays praised the facility in his article "Centre of the Earth" as "...a model of achievement for drawing on few resources and designing them to go a long way."[6] In many ways, the Centre is a model of sustainable design. Ecological issues were considered on multiple levels, from the site and building to component scales. The project responds sensitively to the landscape; the building configuration and massing respond to the climate; passive heating, passive cooling, and daylighting systems were intended to minimize energy consumption; materials were thoughtfully selected in terms of embodied energy and ecological impacts; and health was considered through materials, finishes, and air quality. There are many valuable lessons to be learned from the Boyne River Ecology Center. However, despite the many successes (which are significant), there are also lessons to be learned by addressing and raising the often uncomfortable questions concerning the challenges designers face in integrating new technologies. It is difficult to be critical of a project which goes so far beyond the architectural norm and tackles the complexity of ecologically responsive design. The project's weakness may lie in its attempt to do too much rather than too little. A primary criticism of the project concerns the integration of and dependency on several technological systems which have challenged the users and operation of the facility. The Boyne embodies both strengths and weaknesses; however, when there is a gap between design ideas and the design expression technology often plays a critical role.

It is first necessary to provide an overview of the design intent and current state of the project in order to understand its strengths and weaknesses. The Boyne River Ecology Centre is part of a larger educational complex supported by the Toronto Board of Education. Students from the Toronto school system typically spend one week per year at the 400 acre campus to study ecology and the environment. The facility is located on a stunning rural site in the Niagara escarpment region in Ontario, several hours northwest of Toronto (see Figs. 1 and 2). The Centre was designed as a learning tool for issues of sustainability and ecology. A number of building objectives were set forward by the Toronto Board of Education: 1) The Centre should be built with a near-zero impact on the surrounding area; 2) It should produce all its own energy and treat its own waste; 3) It should be designed to...demonstrate actively through its existence the principles of conservation and respect for the environment; 4) It should prove that building a useful, near zero-impact public structure is technologically and economically viable in Toronto today; and 5) It should demonstrate that the above goals can be accomplished without compromising the inherent beauty and delight of a well-designed structure.[7] The question is whether the goals have been achieved and whether the goals are feasible given the state of sustainable design and technology. To investigate these issues, the architect and clients were interviewed and the building was visited during the past year.

The project sets forth to accomplish worthy objectives and in many ways meets them commendably. Although there are a range of issues which could be discussed, this paper will focus on the role of design and technology as expressed in the heating, lighting, and water systems (for a further description of the facility see Vernon Mays' and Doug Pollard's articles listed in the references). The site is located in a heavily wooded deciduous and coniferous forest which gently slopes to the south and is adjacent to a small pond and the Boyne River (see Fig. 2). The Centre is a two story, sixteen-sided building which is bermed into the hillside on the north and extensively glazed on the south (see Figs. 3 and 4). The first level contains a solar aquatic waste treatment facility - a two story volume oriented due south. The habitable spaces are located on the second floor. At the heart of the building is a fireplace, with classrooms above and to the southeast and southwest of the solar aquatics room, and a lecture room and services located to the north.

HEATING AND COOLING SYSTEMS

The Centre combines a number of strategies for heating and cooling: direct solar gain, thermal mass, an earth berm, heat recovery ventilators, and glazing technologies. The passive solar system was intended as the primary source of heating.

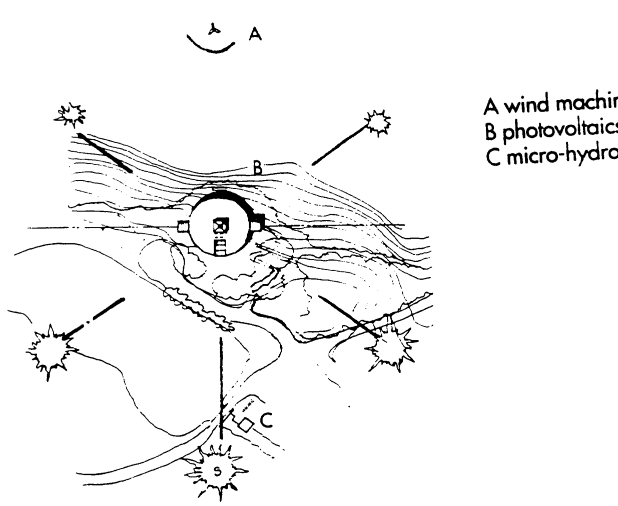

Fig. 2. Site Plan, Boyne River Ecology Centre

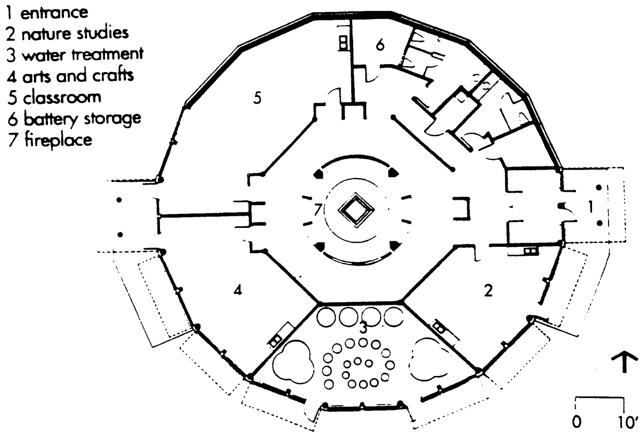

Fig. 3. Plan, Boyne River Ecology Centre

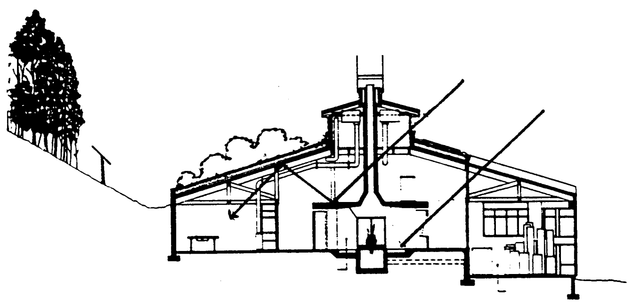

Fig. 4. Section, Boyne River Ecology Centre

During the heating season, the solar aquatics room and the classrooms were designed to collect direct solar radiation and redistribute the heat to the remaining portions of the building (see Figs. 1, 4, and 5). On the second floor, warmed air is allowed to move through openings at the top of interior partitions, while fresh air is passed through a heat recovery ventilator and distributed to the classrooms. During the cooling season, ventilation is provided to the second floor by operable windows. The stack effect then draws warm air through the centrally located cupola. In addition, the building is bermed to the north and has a sod roof to moderate temperature swings throughout the year. Low-emissivity argon-filled glazing is used on exterior windows. After the first year of operations, the combined passive solar and bermed systems appear to be performing fairly well. Preliminary monitoring has shown that relatively comfortable temperatures have been maintained throughout the year (an indoor summer temperature of 26º C in summer and 10º C in winter).[8] An additional strength of the ventilation and heating systems are the numerous visual cues which illustrate to the students the relationship between the facility, site, and climatic forces. Students learn about ecologically responsive design by interacting with the building systems - natural ventilation, the stack effect, and the earth sheltered design all enhance awareness of the site and environmental forces.

Thermal comfort has been an issue of concern despite the numerous heating and cooling systems. According to Mays' article in *Architecture*, "...the center depends primarily on passive solar heating....Backup heating is provided by the fireplace..."[9] Although the systems provide vivid educational opportunities, after one year of operation, the heating system is being redesigned to address thermal comfort and performance problems during the past winter. The solar aquatics room, which is the primary source of direct solar gain, has not met winter heating requirements. The room is located due south, and is glazed from floor to ceiling. Glass partition walls separate the solar aquatics room from the second floor. Health concerns, such as odors and potential airborne microbes, require the single-pane windows in the glass partitions to be non-operable. Heat gathered in the solar aquatics room therefore cannot be vented directly to the inhabited spaces on the second floor - heat must be transmitted through the glazing (see Fig. 4 and 5). The full benefits of the system are not realized due to these conflicting programmatic requirements. The goal was to use the fireplace to supplement heating needs. According to Pollard, "When temperatures reach their lowest the central fire supplies the remaining requirements."[10] The fireplace was intended to provide additional heating, however, complications concerning operation, ventilation, and safety have challenged the users. A new fireplace system and a woodchip furnace are currently under consideration. Although the existing systems do meet partial heating requirements, the anticipated performance has not been achieved. Pollard has done a commendable job in integrating architectural design, passive, and active technologies despite the challenges of the technological systems. It is hoped that technological refinements and continued monitoring will enable the facility to realize its thermal and pedagogical objectives.

ELECTRICAL POWER

Alternative energy generation is a second method employed at the facility to meet both energy and educational objectives. Three systems are used to generate electrical power:

Fig. 5. Solar Aquatics Room, Boyne River Ecology Centre

Wind, hydro electric, and photovoltaics. The wind generator (located on a hill above the center), the photovoltaic array (directly behind the facility), and the hydro generator (located at the head of a pond in front of the building) were designed to provide electricity and to act as teaching tools for the students (see Fig. 2). Each system is designed to respond to seasonal variations, illustrating the changing climatic and environmental forces which influence the site. Students have an opportunity to learn about the generation of electricity while directly monitoring electrical consumption. The power system is a potent tool for visualizing the energy cycle. Despite the obvious benefits of the design, the facility has experienced several technological difficulties which have compromised the effectiveness of the system.

Doug Pollard states that "The facility generates its own power from three sources: wind, sun and water. It is not connected to the grids in any way."[11] The electric power system does not generate a fully renewable electrical supply, however, and the facility has in fact been connected to the local utility system. The three methods of power generation were intended to respond to the different seasonal conditions: photovoltaics would be maximized in the summer, wind in the winter, and hydro electric in the spring and fall. In June of 1994 the wind generator was not working. The photovoltaic panels were supposed to meet the summer demand for electricity; yet this was not achieved during the past year. A strength of the design is that limited electrical power is needed to operate lighting, control systems, and fans. Mays explains the educational intent of the battery storage system in his article: "Electricity from each of the three sources is stored in large batteries behind glass in a room at the rear of the center, where students can view the batteries but not tamper with them."[12] During the past summer, the storage batteries were being charged by electricity purchased from the utility company in order to maintain their storage capabilities until the system could properly charge the batteries. The current system achieves neither the original concept of sustainability nor the full pedagogical objectives. The design theories were sound, but technical difficulties must be overcome before the design intent will be realized. However, the electrical power system does provide a valuable teaching tool to discuss the potentials of these technologies.

LIGHTING SYSTEMS

A delightful aspect of the facility is the extensive use of daylighting. Students have an opportunity to experience the changing quality of light, time, and seasons through well-conceived daylighting in the classrooms and solar aquatic room (see Figs. 3, 5 and 6). The generous sidelighting in the classrooms provides direct visual connection to the site and views to the pond and surrounding landscape. The changing quality of light and shadow are subtle reminders of the apparent movement of the sun. Direct sunlight slips from one room to the next, quietly bringing the facility to life while reminding the students of the diurnal and seasonal cycles. Colorful tile inlays adjacent to the centrally located fireplace illustrate important solar events. Deciduous trees and exterior shading are used to respond to seasonal shading while emphasizing the building's changing solar response.

Very little electric lighting is needed in the facility. Although the solar aquatic room is fully daylit, and significant illumination is provided to the classrooms and entries, the north side of the building could use additional daylighting (see Fig. 3 and 4). A cupola is intended to provide additional toplighting to the central gathering space. However, the fireplace partitions and lack of additional sidelighting to the north of the building effectively eliminate daylighting in the back of the lecture room, battery storage room, north corridor, and restrooms. Energy efficient fluorescent lamps are used throughout the building, with halogen lamps located around the fireplace. According to Pollard, "Switching in the classrooms and circulation spaces is both conventional and touch control - allowing specific lights to be activated on demand."[13] Although this was the design intent, the classroom switching and electric lighting systems were not operating during the site visit. There was no electric lighting in the classrooms at that time. Fortunately the daylighting in the classrooms was adequate to provide general illumination for non-critical tasks. The electric lighting control systems have been problematic. Mays' articles states that "Restroom lights are triggered by motion sensors when someone enters the room; after seven minutes of stillness, the room goes dark."[14] In June, the restroom motion sensors turned off the lights prematurely - leaving a user in the dark. Though both systems have been fine-tuned to meet the needs of the program, such technical failures illustrate the obstacles which still need to be overcome with even straightforward and commonly accepted technologies. The challenges of the lighting technologies are minimized by Pollard's thoughtful integration of daylighting. Despite the technological difficulties, the facility generally provides beautifully daylit spaces which strengthen the students understanding of diurnal and seasonal changes, enhances their relationship to the site and climate, and also illustrate fundamental principles of energy-efficient lighting design.

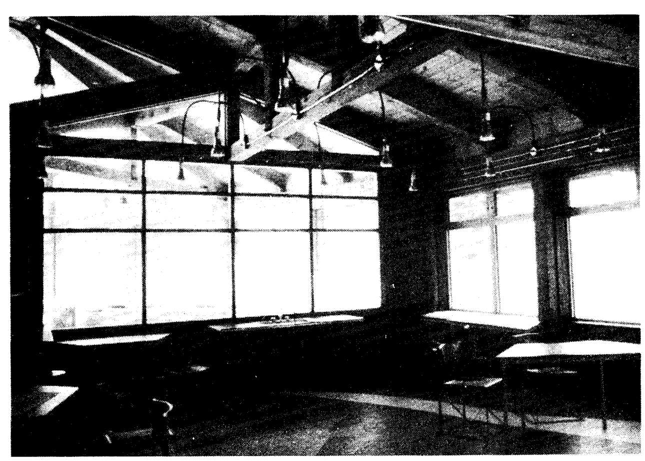

Fig. 6. Classroom, Boyne River Ecology Centre

WASTE WATER TREATMENT SYSTEM

One of the most evocative learning tools for the students is the solar aquatic waste treatment system (located in the solar aquatics room) which is used to purify waste water and sewage (see Fig. 3). The indoor system is comprised of a series of sealed anaerobic and aerobic tanks; gravity fed treatment tanks (containing various types of bacteria, algae, zooplankton, snails, plant life, and aquatic organisms); and an interior marsh (see Fig. 5). Pollard describes the outside components in the following manner "Waste leaving the clear indoor pond is further filtered through an outdoor marsh. The marsh is coupled to an effluent tank at its east end and to an influent sump at its west end. From the effluent tank the water can be diverted to a parallel operational septic tank and leachfield system or can be reused in the building."[15] The system provides tremendous educational opportunities by engaging the students in the process of waste treatment. The series of cylindrical gravity fed tanks are intriguing examples of ecological systems, complete with vegetation and aquatic organisms which illustrate the ecological process - an explicit contrast to traditional waste treatment systems. Students can physically trace the waste cycle from one phase to the next, ending with lush tanks which replicate marsh ecosystems. The solar aquatic waste treatment system is a powerful learning tool which enables students to see waste transformed into a resource.

Unfortunately, the system is redundant - waste is first treated through the biological system and then retreated with a conventional system. Pollard explains that "After a period of observation by the local health authorities it is intended that this reclaimed water will be mixed with UV-treated pond water as part of the main water supply for the building."[16] Building and health codes currently do not allow the system to meet its full potential. Although the system works, there were fabrication problems. At the time of the site visit, a number of the cylinders had failed due to poor construction. According to Mays' article, "The most ambitious aspect of the Ecology Centre is its solar aquatic waste treatment system, which releases cleaner water that it takes from the site..."[17] The question is where the water is being released - it is not being recycled to the building. The solar aquatic system is a significant undertaking. However, due to both current building standards and technical concerns, it remains a conceptual model of sustainability; it has yet to achieve its design intent. Despite these concerns, the solar aquatic room is a valuable educational tool which enriches students understanding of waste cycles and illustrates the potential of ecological systems.

CONCLUSION

In a recent interview on the topic of the environment, Susan Maxman, former President of the AIA, stated that "...we have to be willing to stick our necks out a bit more than we have in the past."[18] The Boyne River Ecology Centre should be praised for its innovative and comprehensive approach to ecological issues. Doug Pollard has made significant accomplishments in terms of sustainability - particularly through his willingness to push architectural standards. Pollard reinforced Maxman's statement in an interview this summer: "...the architectural profession has to be willing to take risks."[19] It is only through taking risks and being willing to implement new ideas, technologies, and systems that lessons can be learned and that progress can be made. It is important, however, to acknowledge that the profession and the building industry are in a process of learning; many concepts, strategies, principles, and products have yet to be tested and refined.

One must view the Boyne River Ecology Center as an important precedent in expanding the scope of sustainable design. Yet despite the many strengths and the apparent (albeit generally reconcilable) technological weaknesses, one must ask what price will be paid for the unrealized intentions? Will the Toronto Board of Education be willing to fund a similar project? Will the challenges and time invested to resolve difficulties by the school administrators and teachers impact their perceptions of the facility and sustainable architecture in general? Does the facility meet the proposed objectives as a model of sustainability and a teaching tool, or do many issues remain at the conceptual level? Technological systems will no doubt be fixed and many of the problems will be resolved, but the initial design intentions and objectives may never be accomplished. One may question whether the original objectives set forward by the Toronto Board of Education were obtainable and whether expectations were too great given the current state of sustainable design.

Several important lessons can be learned from the Boyne River Ecology Center: 1) Many pressing ecological issues can be immediately addresses with careful research and thoughtful design - such as the Boyne's use of passive cooling and heating, daylighting, and climate and site responsive design; 2) Design objectives must be scrutinized to determine whether goals are attainable given current technologies and practice; 3) Post-occupancy evaluation and/or monitoring is critical to ensure that design intentions and design requirements are achieved; 4) New and even commonly accepted technologies require evaluation, testing, and monitoring to ensure proper performance; 5) Practitioners, educators, and the architectural media need to be aware of the distinction between the concept of sustainable design and the practice of sustainable design; follow-up and client interviews should be made to verify performance and to ensure that building claims are being realized; and 6) The profession needs to determine where its strengths and weaknesses lie, and more importantly how they inform the development of sustainable practice.

The state of sustainable design and the role of technology are complex issues. The questions are unclear and the answers are often elusive. As John Tillman Lyle says in *Regenerative Design*, "Many of the technologies are ready for widespread application. Putting them to use, integrating them into the natural and social environment, will require highly sophisticated levels of design."[20] It is necessary to acknowledge this complexity and the difficult work it takes to address issues of sustainability. The profession has much to celebrate in the recent developments and movements toward sustainable design and practice; however, it should not underestimate the magnitude of the task. It needs to continue to challenge and question building standards, raise expectations, and expand its vision of the future. But in doing so, it must continually evaluate its weaknesses as well as its strengths. The path toward a sustainable future will be created incrementally as sustainable practice develops and grows in strength and competency. It is essential to continue defining what works and what does not work, and what is actual versus what is potential. The intent of a project may be quite distinct from what is achieved in that project. Sustainable design can not move forward if improvements are stifled by adopting problematic solutions. The goal is to achieve all that the Boyne River Ecology Centre set out to accomplish; yet to obtain these objectives, the profession will need to honestly assess sustainable technologies and design.

Bill Willers states in *Learning to Listen to the Land:* "The facets of a now perceptible move toward an ecological era are, for the most part, small and in poor communication with one another. As Thomas Berry wrote in 1988, 'We are like a musician who faintly hears a melody deep within the mind, but not clearly enough to play it through.' The melody continues to grow, though, both in strength and in clarity, and as this takes place assumptions that not long ago seemed invincible are crumbling at the edges."[21] The architectural profession needs to share, to listen, and to learn from its lessons.

NOTES

1 Edward Abbey, "Every River I Touch Turns to Heartbreak," *Learning to Listen to the Land*, Washington D.C.: Island Press, 1991, p. 175.
2 Richard Crowthers, *Ecologic Architecture*, Boston: Butterworth Architecture, 1992, p. 71.
3 John Tillman Lyle, *Regenerative Design for Sustainable Development*, New York: John Wiley & Sons, Inc., 1994, p. 13.
4 Ibid., pp. 10-11.
5 Michael Davies, "Changes in the Rules," *Visions for the Future*, London: Academy Group Ltd., 1993, p. 23.
6 Vernon Mays, "Centre of the Earth," *Architecture*, June 1993, p. 52.
7 Doug Pollard, *Boyne River Ecology Centre: The Design of a Totally Self-Sustaining Educational Facility,* Toronto: Doug Pollard Architects, 1993, pp. 1-2.
8 BL, "Eco-Building at the Boyne," *Canadian Architect*, June 1994.
9 Vernon Mays, p. 52.
10 Doug Pollard, p. 4.
11 Ibid., p. 3.
12 Vernon Mays, p. 56.
13 Doug Pollard, p. 4.
14 Vernon Mays, p. 56.
15 Doug Pollard, p. 6.
16 Ibid.
17 Vernon Mays, p. 56.
18 Donald Prowler, "The Environmental President," *Progressive Architecture*, February 1993, p. 104.
19 Doug Pollard, Interview, Toronto, Ontario, June 1994.
20 John Tillman Lyle, p. 13.
21 Bill Willers, Editor, *Learning to Listen to the Land*, Washington D.C.: Island Press, 1991, p. 197.