A catchment can be defined as the area that encompasses a particular aquatic environment (e.g., a lake or a stream) including the land that drains into it. In Sudbury, a catchment can vary from a few hectares of area drained by a small temporary stream to the thousands of square kilometres drained by major rivers in the area.

Catchments can be considered as individual ecosystems with their own sets of biological, physical, and chemical inter-relationships; however, it must be recognized that catchments are linked to each other through processes including material transport that occur in the atmosphere and by hydrologic transport from one catchment to another. Catchments are therefore very important ecological units, but the concept of the catchment is also a very tangible and appealing one from the human perspective. For example, municipal planners have made increasing use of the catchment (or watershed) as the appropriate level for environmental planning (RCPW 1992). The sense that the drainage water leaving a catchment integrates the inputs to the area, as well as the human activities within the area, creates a real sense of “place” for many people and thus a recognition of the need for responsible management planning. Some suggestions and challenges for providing effective management of catchments are the focus of this chapter.

Integrated Approach to Catchment Management

Managing catchments as ecosystems requires that the effort be integrated at various levels or through various processes. First, the efforts of government, industry, academia, and nongovernment organizations must be integrated effectively. This includes establishing agreement on goals for the management of the ecosystem and requires the integration of responsibilities and expertise from a wide cross section of organizations and, in many cases, from within an organization (Flp 24.1). For example, within government, integration must occur at all jurisdiction levels. That is, it is essential that the municipal, the provincial (or state), and the federal government be aware of what every other level is doing and not be working at cross purposes or duplicating efforts.

In the Sudbury region, an excellent example of a successful multidisciplinary group is the Vegetation Enhancer Technical Advisory Committee. This committee, established in 1974, consists of members from the local mining industries, various government agencies, elected politicians, the academic community, public interest groups, and individual citizens. It has successfully developed, initiated, and carried out many projects aimed at improving highly visible barren land in and
around the environs of Sudbury (see Chapter 8).

In a similar manner, scientists and managers must integrate the disciplines needed to examine the various components of the ecosystem (Fig. 24.1). Chemists, biologists, ecologists, hydrologists, atmospheric scientists, and others must work together. This means, too, that methodologies must be consistent among the various scientists and disciplines. Most important, the main subcomponents of the catchment ecosystem, the aquatic, terrestrial, and atmospheric components, must all be considered. Furthermore, it is necessary to study not only the terrestrial, the atmospheric, and the aquatic portions individually but also any interactions among them. For example, although sulfate is deposited from the atmosphere onto both the terrestrial and the aquatic portions of catchments, sulfate falling on forests or soils or wetland areas may be stored there for an extended period and ultimately enter a lake or stream (i.e., as groundwater or run-off) as a consequence of changes in other environmental factors. The questions then become how, when, and in what form.

It is also important when integrating the measurements on the physical and biological components of the catchment not to overlook areas of the ecosystem. In the Sudbury region, for example, very little work has been done on streams. Wetlands and the littoral zone of lakes are other areas that are sometimes underrepresented in sampling and management strategies, but they are important because they link the aquatic and terrestrial environments. This lack of attention implies that these areas are less important as sources or sinks of pollutants or as refuges or dispersal routes for organisms. However, quite the contrary is true (Dillon and LaZerte 1992; Devito and Dillon 1993).

Surveillance and monitoring (i.e., assessment of the status of the ecosystem) and the research efforts of scientists also must be integrated, not only with respect to each other but also with respect to socioeconomic considera-
tions. The establishment of surveillance and monitoring programs is critical to establish "baseline" conditions and to determine natural variation in the ecosystem. Only then can anthropogenic disturbances be readily detected. Although one does not always need these scientific data to demonstrate that an environment is degraded (i.e., it may be intuitive, as is the case in the Sudbury region), survey and monitoring data are necessary to identify less severely damaged areas at a stage at which abatement programs may be more effective. For example, it was only by routine monitoring of precipitation in the Muskoka/Halliburton area of Ontario (350 km south of Sudbury) in the mid-1970s, that the effects of long-range transport of sulfur dioxide on remote ecosystems became apparent (Dillon et al. 1978).

The data from monitoring studies also provide the foundation on which scientific research, including the important core component—predictive models, are built. These research activities allow scientists to predict the effects on the ecosystem of a reduction or an increase in the level of the stressor. The accuracy of these predictions can be tested only if monitoring studies are continued, even after the stress is entirely eliminated. Thus, the integration of monitoring and surveillance programs with scientific research is not only logical but essential. Unfortunately, monitoring is an activity that governments and academia are reluctant to undertake because of the amount of time and money involved. Furthermore, for many scientists, simply "describing the extent of the damage" (or lack thereof) is considered to be boring (Haukijärvi 1993). In other words, there is little interest in characterizing pristine ecosystems or in monitoring what is often a very gradual response to long-term changes in stressor levels. Thus, monitoring and surveillance programs often may not be initiated early enough to establish the initial conditions of the ecosystem.

The integration of scientific endeavors (monitoring, surveillance, and research) with socioeconomic considerations is perhaps the most important area of integration in terms of overall catchment management. This marriage of science and society is essential to produce sound management policies a priori and/or, in situations in which the stress has already occurred (such as in Sudbury), sound rehabilitation or remediation practices. The return of highly damaged areas to conditions that even closely resemble "historical" conditions (i.e., restoration) is often not possible (Moore and Luoma 1990). Thus, it is important for society to be able to assess the benefits (e.g., economic, health, environmental) to be achieved through reducing the magnitude of the stressor before deciding how much stress they are willing to let an ecosystem tolerate.

Environmental Protection Model for Managing Catchments

Recently, Somers et al. (1994) developed a conceptual model of the environmental protection process (Fig. 24.2) that shows the inter-relationship between monitoring/surveillance activities (collectively termed assessment in their model), scientific research, policy development, and reporting. This model is directly applicable to management of industrial areas such as the Sudbury region and emphasizes the need for integration at many different levels. Step 1 involves reporting on the state of the ecosystem. This requires sound and extensive data that have been collected through monitoring activities (temporal patterns) and surveys (spatial patterns). The response of the public, non-government agencies, government, industry, etc. (step 2) can then be used to set or revise the ecosystem goals or objectives (step 3) (i.e., what society views as acceptable conditions). These are then used to judge if the current state of the ecosystem is acceptable or unacceptable (step 4). If the ecosystem is acceptable, then the "assessment" or monitoring/surveillance loop is followed. Ongoing characterization of the ecosystem through monitoring programs allows for the establishment of baseline conditions (step 5). However, because it is impossible to monitor all components of the ecosystem, chemical, physical, and/or biological indicators of ecosystem health are selected (step 6). This usually requires some sort
of scientific research. Then, by using these indicators together with an idea of what the normal ecosystem should look like, scientifically based objectives that satisfy the goals established in step 3 can be developed (step 7). However, as mentioned earlier, continued monitoring and surveillance is required (step 8) to ensure that the ecosystem goals and objectives are met.

However, if in step 4 the state of the environment is deemed to be unacceptable, then the prevention/remediation loop is followed. First, the stressor must be identified (step 9), usually through scientific research efforts. Once the stressor is identified, its origin, fate, and mode of action must be evaluated and modeled (step 10) so that the effect of the stressor on the ecosystem indicators can be predicted. This allows for the assessment of remediation or regulatory actions (step 11), followed by implementation of the preferred options (step 12), which usually includes a reduction in the levels of the stressor. Although the worst scenario, it may include only ecosystem manipulation designed to counter the effects of the stressor without reducing the magnitude of the stressor. Then, as in the assessment loop, monitoring programs must be pursued to assess the compliance and effectiveness of the prevention/rehabilitation strategy. The prevention loop is identical to the rehabilitation loop except for the fact that prevention is initiated before the ecosystem damage.

In summary, the integration of monitoring and research data with socioeconomic factors means that although scientists can collect data, test hypotheses, and make recommendations, it is the responsibility of many people, often most important, the public, to determine the direction that management policies will take. An excellent example is provided by the city of Sudbury, which recently used an "ecosystem approach" to lake management to develop an award-winning community improvement plan for Ramsey Lake (see Chapter 25).

Specific Management Issues in the Sudbury Region

As shown in previous chapters in this book, management of the Sudbury region as a whole generally provides a test of the integrated approach to catchment management.
(see Fig. 24.1). First, the ability to manage and the responsibility for management of the area has rested with and continues to rest with many organizations including government, industry, academia, and non-government organizations, but an informed public is increasingly becoming the force that ensures that these agencies honor these responsibilities. Second, a very significant body of scientific data, representing most contaminants of the ecosystem has been collected by hundreds of scientists over the past 30 years, beginning with the first published studies by Gorham and Gordon (1960). Finally, these data have provided the foundation for sound management practices and for the development of restoration techniques relevant to the regional problems.

Difficulties in Applying the Integrated Approach

Despite this potential for an integrated approach to catchment management, serious challenges have and still are faced by those attempting to set policies for the Sudbury region. The reasons for the difficulties stem from the fact that pollution often has no political, geographical, social, or temporal boundaries.

Secondary and Tertiary Pollution

First, as illustrated in Figure 24.3, there is the problem of secondary and tertiary pollution. This means that one cannot only look at one ecosystem (catchment) in isolation but also must study those downstream and downwind of that catchment. Most lakes in regions that have been glaciated have an outflow. Consequently, the presence, for example, of elevated metals in a lake means that potentially all the lakes downstream of it may become contaminated with metals (Dillon et al. 1982). This is illustrated by the fact that large areas of metal-contaminated sediments have been documented at the mouths of rivers that drain the Sudbury area (Plichtova 1978; Spanish Harbour Rap Team 1993), as is the case in other metal smelting areas of the world (Baumann 1984; Moore and Luijoma 1990). Similarly, although the completion of the 341-n Superstack in 1972 alleviated the unacceptable air quality conditions in Sudbury, it increased the area
affected by high sulfate and metal (copper and nickel, primarily) deposition, it has been estimated that as much as 97% of the sulfur emitted from the Sudbury smelter is carried farther than 60 km from Copper Cliff and, thus, contributes to major widespread problems of acid deposition (Hutchinson 1982). This, what was perceived to be an acceptable solution to the local problem may have far ranging consequences (Fig. 24 A).

Time Scale

Another consideration in managing areas such as Sudbury is one of time scale. From a management perspective, this is an issue because both short-term and long-term remediation efforts must be considered and the relative effort to be placed on each must be assessed. Thus, efforts spent on rehabilitation techniques such as lake liming (see Chapter 15) (Bidder et al. 1993; Mejot et al. 1986, 1990) or fertilization (Yan and LaFrance 1984), fish stocking, and watershed liming and fertilization, which are the only short-term solutions to the long-term problem (Stevan et al. 1984), are not a substitute for reducing the levels of the stressors. These must be weighed against the efforts invested in establishing the acceptable sulfur and metal emissions and deposition rate.

From a scientific perspective, time presents a problem with respect to determining long-term or substantial effects of the events on the ecosystem. Although the extinction of fish species such as the masu trout (see Chapter 11), the loss of entire fish populations (Bignall and Stanley 1972; Bignall 1974), and the degradation of the landscape (see Chapter 2) are obvious and direct lethal effects of high acid and metal deposition, long-term or elusive effects on lakes are not so readily discernible. For example, the copper concentrations in many of the Sudbury area lakes typically exceed 2 μg/l (Keller et al. 1992) (i.e., are greater than the provincial water quality objectives. Although the copper levels
interactions between stresses

The interaction between stresses is another problem that became apparent during the integrated studies carried out in Sudbury. One example is forest denudation (resulting from both logging activities and acid metal deposition), which led to increased soil erosion, higher surface reflective temperatures, and enhanced frost action (see chapter 18). A second example is the interaction between sulfate (and H+ ion) deposition and trace metals. Because of smelting activities, copper and nickel concentrations in soil, water, and biota are elevated in the immediate vicinity of Sudbury. Thus, biota must contend not only with high metal levels but also with low pH. It has been well documented that pH can have a synergistic (i.e., enhancing) effect on metal toxicity (e.g., Campbell and Stokes 1985; Cust-

van et al. 1986; Hutchinson and Sprague 1986; Hickle et al. 1993). For example, Welsh et al. (1993) found that the toxicity (expressed as the 96-hour LC50 of copper to fathead minnows (Pimnoela promelas) increased fourfold as pH decreased from 7.2 to 5.6.

Acid precipitation can also cause leaching and mobilization of other metal ions such as calcium, magnesium, aluminum, manganese, iron, and zinc from soils and bedrock (Mayer and Ulrich 1980; Jeffries et al. 1984). As a result, biota that are in ecosystems remote from industries that emit metals into the atmosphere may have to contend with the combination of high levels of both acid and metals.

A discussion of the complexities of metal-H+ or metal-metal interactions is beyond the scope of this chapter. However, depending on the organism in question as well as the mitigating circumstances in the lake/soil, the toxicity of chemical "mixtures" can be either (1) synergistic (i.e., the presence of one enhances the toxicity of the other), (2) additive (i.e., the presence of one adds to but does not have an effect on the toxicity of the other), or (3) antagonistic (i.e., the presence of one decreases the toxicity of the other, e.g., selenium/mercury, calcium/aluminum). When making policy decisions for a catchment, one must be aware of these potential interactions and, as discussed previously, conduct "integrated" scientific research.

External factors

Although scientists can study, model, and predict to a certain extent the effects of these multiple stresses on the ecosystem, factors external to the principal stressors often can impinge on the situation and complicate the issue. A few examples follow.

Climate/weather change

As discussed above, wetlands, soils, and even the littoral zone of lakes are able to store strong acid in the form of reduced sulfur com-

in the worst cases are high enough to be acutely toxic to some biota, in many cases the effects may be chronic and therefore less readily observable.

Time presents a complication when managing systems for another reason. It is known that the capacity for the terrestrial and wetland portion of catchments to "store" strong acids (in the form of reduced sulfur compounds) and trace metals is high (Urban et al. 1989; Dillon and LaZerte 1992). However, evidence has shown (Bayley et al. 1987; RMCC 1990) that terrestrial areas may release these compounds for periods of years to decades. For example, in Plastic Lake, Ontario, the pH and acid neutralizing capacity (ANC) of the water decreased gradually from 1979 to 1985, despite the fact that atmospheric deposition of sulfate and strong acid decreased sharply during that same period (Dillon et al. 1987). The reason for this is that the wetlands in the catchment continued to supply sulfate to the water despite the reduction in the sulfate deposition. A similar situation has been documented in the Sudbury area (Keller et al. 1992). Thus, detrimental effects on biota may be observed and measured long after the stress (i.e., sulfate deposition) has been reduced or even eliminated. This presents a challenge to scientists who must try to predict the effect of the stress (see step 10 in Fig. 24.2) without knowing its future level in the ecosystem.
pounds. Catchment mass balances have shown that the storage of sulfate and/or the oxidation of stored reduced sulfur usually occurs during dry seasons (Dillon and LaLzen 1992) or in dry years when the water table becomes lowered. At the beginning of the next wet season, or in a wet year, the stored sulfate is then released back into the outflowing waters. Given that you cannot predict the weather, it is difficult to imagine managing a catchment if you are unable to predict when these pulses of acid might occur. However, long-term monitoring studies might provide insight into climatic trends and thus allow for modeling efforts.

Decrease in Atmospheric Ozone

The recent attention given by the scientific and non-scientific communities to the decrease in the ozone layer also has consequences with respect to biota in the Sudbury region. It is well documented that ultraviolet (UV) radiation can have detrimental effects on biota and that UV levels that lakes and other ecosystems are experiencing are increasing as a result of a decrease in ozone levels in the upper atmosphere. It is the dissolved organic matter (usually measured as dissolved organic carbon [DOC]) in lakes that absorbs strongly in the UV range. Unfortunately, acidification results in the reduction of DOC levels in streams and lake water (Dillon et al. 1987), and the soft water, low alkalinity, acidic lakes typical of the Sudbury region generally have low DOC concentrations. Thus, they are particularly vulnerable to a decrease in the ozone layer.

Nitrate Release from Catchments

After sulfate, deposition of nitrogen compounds is the next most important class of anthropogenic acids entering aquatic systems in Canada (RMCC 1990). However, emission of NO and deposition of related compounds should not be directly influenced significantly by mining/ smelting activities but perhaps indirectly because most mining industries make massive uses of energy, which is often derived from the combustion of fossil fuels. Thus, although emissions of sulfur dioxide and declines in the atmospheric deposition of SO2 may have occurred in Ontario since the mid-1970s, NOx emissions and NO deposition have not decreased (Dillon et al. 1988). In the past, this has not been thought to be a problem because terrestrial ecosystems are often limited by nitrogen, and, thus, they have been a sink for nitrogen inputs (Driscoll and van Dreason 1993). However, declining vegetational demands coupled with increased deposition of nitrogen from the atmosphere may result in saturation of the terrestrial ecosystem.

Consequently, in Europe and in parts of the northeastern United States, there has been evidence of surface water acidification resulting from elevated NOx (Herniksen and Brakke 1988; Driscoll and van Dreason 1993). This means that even if large-scale reductions in sulfur dioxide emissions were implemented, recovery of lakes from acidic deposition may be delayed due to offsetting increases in NOx concentration.

Other Stresses

Kelly Lake in Sudbury, like several other lakes in the region that have calcareous deposits in their catchments, at present is not adversely affected by acidification, even though it lies at the center of the high sulfate deposition zone. However, it is the recipient of sewage from the city of Sudbury and, thus, suffers from all the problems typical of municipal lakes—it is eutrophic, bacterial counts often exceed guide lines established for human health protection, and macrophytes proliferate along its shoreline. It is important for those who are involved in management decisions for communities, such as Sudbury, that are affected by mining activities, not to overlook lakes such as Kelly in their eagerness to remediate only those lakes that have problems due to smelting activities. However, there may be indirect links between acid rain and eutrophication. Caraco et al. (1993) suggested that anthropogenically induced increases in sulfate concentrations in lakes can cause an increase in the magnitude of phosphorus released from the sediments, as well as an increase in the availability of that phosphorus to biota. Thus, two seemingly independent stressors may, in fact, behave in an
inter-active way, again demonstrating it is ap-
parent that the need for integrated research and
management policies is essential to overall
catchment management.

Summary
The management of catchments that have been
damaged by anthropogenic activities or that
may be potentially stressed in the future is a
complex problem requiring (1) an informed public,
(2) the cooperation of many individuals,
government agencies, and non-government or-
ganizations, (3) the coordination of all scientific
endeavors, and (4) the consideration of both
scientific and socioeconomic factors. Conse-
quently, in this chapter, we have described and
emphasized the need for an integrated whole-
ecosystem approach to catchment management
(see Fig. 24.1).

Although the management in the Sudbury area
generally has set an example of how the
integrated approach to catchment manage-
ment should work, serious challenges have
been faced by those attempting to set policies
for the region. The reasons for these difficulties
arise from the fact that pollution transcends
political, geographic, social, and temporal boun-
daries. Secondary and tertiary pollution (see
Fig. 24.3) and multiple stresses such as iner-
actions between sulfate and trace metals and
forest denudation leading to increased soil
erosion, higher surface reflective tempera-
tures, and enhanced frost action have compli-
cated scientific findings. Sulfur storage in the
terrestrial and wetland portions of catchments and
its potential release long after sulfate de-
position has been reduced also presents a
challenge to scientists who must try to predict
the effect of the sulfate without knowing its
future concentration in the ecosystem. Also,
the element of time confuses the issue, not
only for the scientist, who must determine
both long-term (chronic) and short-term (acute)
effects of the stress on the ecosystem but also
for the manager, who must weigh the advan-
tages/disadvantages of short-term versus long-
term remedial actions.

Other factors, external to the principal stressors
(high sulfate and metal deposition) can affect the
Sudbury region and complicate matters even further. These include climate or weather changes, decreasing ozone levels in the
atmosphere, nitrate release from the ter-
restrial portion of the catchment, and phos-
phorus inputs from sewage.

In conclusion we emphasize that only when
scientific research activities are integrated with
responsible and reasonable management pol-
icies can overall catchment management be
successful.

References
Baumann, A. 1984. Extreme heavy metal concen-
trations in sediments of the Oker-a river drain-
ing an old mining and smelting area in the Harz
Mountains, Germany, pp. 579-591. In J. Nitagi
(ed.). Environmental Impact of Smelters, Ad-
vances in Environmental Science Series. John
Wiley and Sons, New York.
Bayley, S.E., D.H. Vitt, R.W. Newbury, K.G. Beany,
R. Behr, and C. Miller. 1987. Experimental accu-
ification of a Sphagnum-dominated peatland: first
Beanish, R.J. 1974. Loss of fish populations from
unexploited remote lakes in Ontario, Canada as a
consequence of atmospheric fallout of acid. Wa-
ter Res. 8:65-95.
Beanish, R.J., and H.E. Harvey. 1972, Acidification
of the La Cloche Mountain Lakes, Ontario and
29:1131-1143.
Campbell, P.C.G., and P.M. Stokes. 1963. Acidifica-
tion and toxicity of metals to aquatic bioa. Can.
fate control of phosphorus availability in lakes: a
test and re-evaluation of Basler and Einsele's
1986. Effects of pH on the toxicities of cadmium,
copper and zinc to scraphead trout (Salmo gairdneri),
De Vito, K.J., and P.J. Dillon. 1993. The influence of
hydrologic conditions and pest oxidation on the
phosphorus and nitrogen dynamics of a cornfield
The use of calibrated lakes and waterbodies for
estimating atmospheric deposition near a large point source. Water Air Soil Pollut. 18:241–258.
35: 809–815.
Dillon, P.J., and B.D. Lazerte. 1992. Response of Plastic Lake catchment, Ontario, to reduced sul-
Dillon, P.J., M. Lusić, R.A. Reid, and D. Vap. 1986. Ten-year trends in sulphate, nitrate and hydro-
Dillon, P.J., R.A. Reid, and E. de Grosois. 1987. The rate of acidification of aquatic ecosystems in
Dillon, P.J., N.D. Yan, W.A. Scheider, and N. Conn-
roy. 1979. Acidic lakes in Ontario, Canada: char-
acterization, extent and responses to base and nutrient additions. Arch. Hydrobiol. Betih. 13:
317–336.
Driscoll, C.T., and R. van Dreessen. 1993. Seasonal and long-term seasonal patterns in the chemis-
Fitchko. Y. 1978. The distribution, mobility and ac-
cumulation of nickel, copper and zinc in a river system draining the eastern part of the metal-
Gorham, E., and A.G. Gordon. 1960. The influence of smelter fumes upon the chemical composition of
lake waters near Sudbury, Ontario and upon the surrounding vegetation. Can. J. Bot. 30:477–
487.
Hauköö, E. 1993. Research on ecological effects of
In M.V. Kosov, E. Hauköö, and V. Varmšelkši (eds.). Aerial Pollution in Kola Peninsula. Pro-
cedings of International Workshop, April 14–16, 1992. St. Petersburg, Russia. Kola Scientific Cen-
ter, Apatity, Russia.
Technol. 18:176–186.
Henriksen, A., and D.P. Brakke. 1988. Sulfate depo-
Hickie, B.E., N.J. Hutchinson, D.G. Dixon, and P.V.
Hodson. 1993. Toxicity of trace metal mixtures to
alvinio rainbow trout (Omorhynchus mykiss) and larval fathead minnow (Pimephales promelas) in
Hutchinson, N.J., and J.B. Sprague. 1966. Toxicity of
trace metal mixtures to American flagfish (Lo-
danelia fluviorum) in soft, acidic water and implica-
Hutchinson, T.C. 1982. The ecological consequences
of acid discharges from industrial smelters, pp. 105–
Geochemical interactions of watersheds with pre-
cipitation in areas affected by smelter emissions
(eds.). Environmental Impacts of Smelters. Ad-
vances in Environmental Science Series. John Wi-
ley and Sons, New York.
Chemical responses of acidic lakes in the Sud-
bury, Ontario area to reduced smelter emissions,
Mayer, R., and B. Utlitch. 1980. Input to soil, espe-
cially the influence of vegetation in intercepting and
modifying inputs—a review, pp. 173–182.
In T.C. Hutchinson and M. Havas (eds.). Effects of
Acid Precipitation on Terrestrial Ecosystems. Ple-
num Press, New York.
Whole-lake and nearshore chemistry in Bowland
Lake, before and after treatment with CaCO3. Can.
Neutralization of acidic lakes: short-term dissolu-
tion of dry and stirred calcite. Water Res. 20:
797–761.
wastes from large-scale metal extraction. Envi-
Research and Monitoring Coordinating Committee (RMCC). 1990. The 1990 Canadian Long-Range
Transport of Air Pollutants and Acid Deposition Assessment Report. Part 4. Aquatic Effects Stud-
ies, Toronto, Ontario.
Royal Commission on the Future of the Toronto
Waterfront (RCPFW). 1992. Regeneration: Tor-
onto’s Waterfront and the Sustainable City (Final Report), Toronto, Canada.
Sornes, K., G. Miere, and N.D. Yan. 1994. An Environ-
nmental Protection Model for the Man-
agement of Ontario’s Water Resources. Technical
report. Ontario Ministry of Environment and En-
ergy, Ontario.

