WETLAND SCIENCE RESEARCH NEEDS IN CANADA

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by

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PREFACE

Many agencies in Canada are presently reviewing the way they study and manage wetlands. In order to help in this task, a workshop on wetland hydrogeochemistry and habitat issues was held at the Canada Centre for Inland Waters, Burlington, Ontario, March 19-21, 1991. Wetland scientists and managers were brought together to review recent advances in wetlands science and identify research and information needs that Canadians must respond to in coming years. The workshop held a series of formal presentations by scientists followed by workshops in which participants worked together to identify research and information needs and develop recommendations.

The purpose of this paper is to report on the 62 research and information needs for wetland science that were identified in the workshop. This paper is a condensed version of the report entitled, Research and Information Needs for Canadian Wetlands, Environment Canada (1991).

FOREWORD

This workshop was conceived with four objectives in mind. The first was to inform science experts and managers of the most pressing wetland research and monitoring needs facing Canada today. Secondly, the workshop was designed for the benefit of scientists, to summarize state-of-the-art information regarding various aspects of wetlands science. Thirdly, a series of recommendations were sought from the range of expertise and opinion present to orient new or existing studies. Finally, recommendations were requested for various organizational initiatives to facilitate the imposing task of understanding wetlands.

Most of these objectives were achieved due to the significant effort and flexibility demonstrated by the workshop participants and the facilitators (ESSA Environmental and Social Systems Analysis Ltd.). Their insight and ideas form the basis of this report.

The workshop would not have been possible without the support of a number of groups. These include several agencies in Environment Canada:

- Inland Waters Directorate, Atlantic Region (S. Fenety);
- Inland Waters Directorate, Headquarters (R. Hélie);
- National Hydrology Institute and National Water Institute (R. Daley and D. Milne);
- Inland Waters Directorate, LRTAP scientific coordinator (D. Jeffries);
- Environmental Integration Service and Air Quality and Environmental Research Branches of the Atmospheric Environment Service (T. Brydges, H. Martin and A. MacMillan);
- Canadian Wildlife Service, Headquarters (G. Lee); and
- Coordinator, Northern Wetlands Research Project (W. Glooschenko).

The Organizing Committee was composed of T. Clair (Chair), W. Glooschenko, R. Lawford, W. Nicholaichuk and C. Rubec. The Organizing Committee thanks all the participants for their energy and enthusiasm throughout the workshop. We also wish to express our appreciation to the North American Wetlands Conservation Council (Canada) for editorial, production and distribution assistance in conveying the information in this paper to a national audience.

One of the key strategies identified in The Federal Policy on Wetland Conservation, released by the Minister of the Environment in March 1992, is the establishment of a sound base for Canadian wetlands science and research. The identified research needs and recommendations presented here make a substantial contribution to the ongoing process for implementation of effective wetland science, management and conservation strategies and policies in Canada.

Thomas Clair, Workshop Chair

SUMMARY

Key knowledge and information gaps regarding aspects of Canadian wetland science were identified under three categories: natural hydrogeochemical processes; effects of human activity; and wetlands as wildlife habitat. Twenty-five specific research and information needs (numbers 1 to 25) were identified to widen our understanding of the natural hydrogeochemical processes of wetlands. More basic research in this area is crucial to developing knowledge of the effects of human impacts on wetlands. These research needs include:

- carbon and nutrient cycling, exchange and storage;
- the role of metal mobilization;
- internal wetland hydrological dynamics and hydrological links with external systems;
- links between geochemistry and hydrology; and
- wetland evolution and ecosystem dynamics.

Sixteen research and information needs (numbers 26 to 41), related to the effects of global climate change, atmospheric pollution and land use activities, were identified. Important research needs that will widen our understanding of the effects of these human-induced perturbations on wetlands are the:

- role of the water table in wetland function and integrity;
- interaction of temperature and moisture in wetland soils;
- nitrogen dynamics in wetlands;
- influence of acidic precipitation;
- long-term response of wetlands to agricultural practices; and
- efficacy of "no net loss" wetland conservation policies.

A total of 21 research and information needs (numbers 42 to 62) relating to wetland habitat were identified. The knowledge gaps relating to wetlands as habitat were both diverse and numerous. Broadly grouped, they included acquiring a better understanding of:

- wildlife responses to wetland change;
- the role of limiting factors such as precipitation, temperature, and water quality on the distribution of organisms;
- interactions between differing habitats, both natural and altered;
- impacts on wetlands of atmospheric and stream deposition; and
- wetland succession and restoration.

To effectively address these knowledge gaps, integrated inter-institutional wetland research is necessary. Similarly, management approaches must also be integrated. To this end, workshop participants developed four recommendations relating to the infrastructural and organizational requirements for such research. Four additional recommendations for improving wetland inventory and monitoring mechanisms were also provided. These eight recommendations are focused as follows:

- developing effective policies nationally for protecting and conserving wetlands;
- establishing a network to coordinate national wetland research;
- developing wetland centres of excellence;
- establishing a subvention grant program for wetland research;
- integrating existing data into comprehensive databases and inventories;
- developing well-designed monitoring programs;
- developing ecological and jurisdictional integration of wetland classification systems;
- developing a comprehensive national wetland inventory.

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INTRODUCTION

In spite of the fact that wetlands occupy an estimated 14% of Canada, we know relatively little about them. However, significant strides in synthesizing Canada's existing knowledge base on wetlands have been completed (National Wetlands Working Group 1986, 1988). Historically, wetlands have been perceived as wastelands to be drained and/or filled to accommodate urban expansion, agriculture and forestry. We now know, however, that wetlands play crucial physical and chemical roles which profoundly influence the health and functioning of ecosystems. If wetlands are to be conserved for the future, their management must be based upon a sound understanding of their function and interaction with the environment. The benefits they provide for maintenance of ecosystems, both for humans and wildlife, must be recognized.

The Federal Government has recognized the need to explicitly identify the key knowledge and information gaps regarding the physical and chemical aspects of Canadian wetlands. To this end Environment Canada hosted a national workshop on wetland hydrogeochemistry in Burlington, Ontario on March 19-21, 1991. The workshop consisted of a formal review of recent advances in wetland science. Following the meeting, the participants met to identify wetland research and information needs. The purpose of this paper is to present the wetland information needs that were identified in the workshop, with the hope that doing so will provide impetus toward resolving them.

There is considerable scientific and public interest in the effects of broad-scale anthropogenic perturbations (e.g. climate change and acid rain) on wetlands, and the role that wetlands may play in ameliorating the effects of these stresses on the biosphere. An attempt to fully comprehend these effects must be based on an understanding of the natural dynamics of wetlands. This rationale has partially dictated the structure of this paper. The second section examines the information needs as they relate to fundamental wetland hydrogeochemical processes. Naturally, the depth of our understanding of these processes will limit our level of understanding of the effects of anthropogenic perturbations. The third section examines the information needs that are more directly related to the effects of human-induced perturbations. While there is overlap between these two sections, they are kept separate in this report to emphasize the need to base our understanding of perturbations on an understanding of natural dynamics. The fourth section examines the information and research needs associated with what many people consider to be the most important function of wetlands: the provision of wildlife habitat.

The recommendations that emerged from the workshop are presented at the end of this paper. Many of these recommendations are intended to address more than one of the research and information needs identified in the previous sections.

In general, each of the recommendations that emerged from the workshop discussions relates to one of two types of activities:

- developing infrastructural and organizational services and capabilities; and
- developing inventory, monitoring and research tools and mechanisms.

Although these categories of activities are not entirely discrete, they do form a useful framework for discussing the recommendations.

The information needs identified in this paper are, by necessity, broad in scope. It is recognized that by identifying broad needs there is a danger that some specific needs may "fall between the cracks". It is not the intention of this paper, however, to identify all important research and information needs related to wetlands, but rather to identify some of the pressing information needs and to draw attention to the necessity of making progress towards resolving these needs given the important role that wetlands play in Canada's ecosystems.

NATURAL HYDROGEOCHEMICAL PROCESSES

Research and information needs were discussed under the following fundamental wetland processes:

- Geochemical Processes
- carbon and nutrient cycling, exchange and storage
- metal mobilization

- Hydrological and Hydrometeorological Processes
- internal hydrological dynamics
- hydrological links with external systems

- Ecosystem Interactions
- linkages between geochemistry and hydrology
- wetland evolution and ecosystem dynamics

There is considerable overlap between these categories. The intent in using them is not to suggest that all concerns can be conveniently categorized into one or the other, but merely to provide a structure for discussion.

GEOCHEMICAL PROCESSES

Carbon and Nutrient Cycling, Exchange, and Storage

Nutrient cycling, in essence, defines the biological productivity of wetlands. Because the availability of nutrients greatly influences the suitability of wetland habitats for plants and animals, an understanding of nutrient cycling will improve our understanding of the biological value and function of wetlands.

In this discussion, particular emphasis was placed on carbon cycling because of the significant role that carbon compounds play, through trace-gas chemistry, in influencing the global carbon cycle. This aspect of wetlands is also a focus of the investigations of the Canadian Northern Wetlands Study (Mortsch 1990, Schiff and Barrie 1988).

Specific information needs related to element cycling in wetlands include:

1. The size and source of the carbon sink in peatlands: The role of the natural sources and sinks of carbon gases and compounds is not well understood. Peatlands are known to produce and store both carbon dioxide and methane (CO_2 and CH_4) (Mortsch 1990). Both are significant "greenhouse gases"; however, the amounts of each contained in peatlands are not known. This is a very significant information gap because Canada's peatlands make up a considerable portion of the earth's total.

2. The rates of accumulation of carbon and organic material in peat: To understand the role of peatlands in the natural environment, it is important not only to quantify the amount of carbon compounds peatlands contain, but also to develop an understanding of the mechanisms and rates of their accumulation.

3. The processes involved in nitrogen, phosphorus, and sulphur cycles in wetlands: Similar to Research Needs #1 and #2 above, nutrient cycling both controls and is a part of wetland biological processes. It is critical to develop an understanding of such cycling before we can fully comprehend the role that wetlands play in the environment. This need is pronounced in both southern freshwater wetlands and northern peatlands.

4. The role that organic materials play in the production and storage of carbon, nitrogen, phosphorus, and sulphur: This role is clearly a component of those listed above, but is mentioned separately because of the vast amounts of organic material stored in wetlands.

Metal Mobilization

Although it is known that wetlands can play a major role in sequestering metals or releasing them into surface waters, the variety of processes, which together substantially alter the chemistry of waters moving through wetlands, is not well understood. In recent years, the acid precipitation issue has stimulated substantial advances in this area, but our understanding of these processes remains primarily descriptive rather than predictive.

Specific information needs identified relate to:

5. The role that wetlands play in the mobilization of trace metals: Because of the relative toxicity of some metals (and their potential impact on ecosystem health), it is important to develop an understanding of the role that wetlands play in the dynamics of metal movement through the environment.

6. The role that wetlands play in "buffering" contaminants: This information need is clearly related to Research Need #5 above, but emphasizes a different aspect of the process. Although wetlands are thought to have value for their ability to retain some metals for long periods, there is conflicting evidence as to whether this is an accurate assessment of the potential of some wetlands (Jones *et al.* 1986, Anderson 1986).

7. The effects of pH on the mobility of organically-bound harmful metals: The chemistry of organically complex metals in wetlands is complicated. Low pH is known to affect the mobility of some metals but the relationship is difficult to quantify.

HYDROLOGICAL AND HYDROMETEOROLOGICAL PROCESSES

Internal Hydrological Dynamics

In this workshop, gaining a better understanding of the frequency and magnitude of water storage changes in wetlands was sought. It is well known that wetlands act as runoff source areas under wet conditions and as storage areas and runoff attenuators under drier conditions (Woo and Valverde 1981, Taylor and Pierson 1984). Many important uncertainties exist, however, about the temporal and spatial dynamics of water storage in wetlands.

Specific information needs identified relate to:

8. Water storage ability of peatlands: All wetlands, not just peatlands, can play a central role in water storage within the watersheds containing them. In fact, their importance is often disproportionately greater than their size relative to the total catchment area. This is an important research need because peatlands make up an estimated 90% of Canada's total wetland area, and because the importance of quantifying the water storage ability of wetlands is most marked for peatlands.

9. The role of permafrost in influencing flow regimes: Because permafrost restricts the vertical flow of water, the capacity of northern wetlands to attenuate flood peaks and sustain baseflow during dry periods is probably limited. However, the precise role of permafrost in influencing flow regimes is not well understood.

10. Seasonal water table changes in wetlands, particularly in small catchments: Although we know that, in general, wetlands hold water during times of high flow and release it during times of low flow, a better grasp of this role is needed. This is particularly important for small catchments because these systems are the most likely to be hydrologically affected by wetlands.

11. Effects of episodic water table changes in wetlands: The response of wetlands to episodic inputs of water is not well understood. How rapidly different types of wetlands respond to storm and drought events requires investigation.

12. Effects of water table changes on wetland type: Major wetland types are distinguished by the extent to which they interact with groundwater; one major aspect of the swamp-bog continuum is exposure to groundwater. Aside from general ecological relationships, specific information is required concerning the influence of the water table on wetland gas dynamics, productivity, decomposition rates, and water retention properties.

13. Hydrologic information on a regional scale: There is a serious shortage of good hydrological information (e.g. hydrometric data) on a regional scale, particularly for small catchments. This information need is directly related to those mentioned earlier, but has other implications as well because many systems are likely to be hydrologically affected by wetlands.

Hydrological Links with External Systems

Wetlands are hydrologically linked to the atmosphere and to terrestrial and aquatic ecosystems. The discussions centred on the information needs associated with these linkages.

Specific information needs include:

14. Identification of wetlands which have valuable hydrologic functions: Wetlands with significant hydrologic value need to be identified in an integrated manner throughout Canada (some regional efforts have been made). Given that this is a potentially important aspect of wetlands, which should be considered in their management, it is critical to resolve this information need.

15. Groundwater-surface water linkages: This information need overlaps with several of those discussed in a previous section. More information is needed on the dynamics of the hydrological linkages between the different wetland types and groundwater.This will enable us to better understand the role of wetlands in influencing groundwater, and how to manage the former in light of this role.

16. Vertical transport of water in peatlands: This information need is a component of the previous one, but bears independent mention because of its significance. The acrotelm (unsaturated zone) of a wetland is the upper and most active layer and is the most interactive with the atmosphere. As a result of such interactions with the atmosphere, relatively large fluctuations in temperature and moisture occur in this zone. The temperature and moisture regimes of the acrotelm are interdependent, and both greatly influence the water table. They also influence the rates of peat production and decomposition. In turn, peat production and decomposition greatly influence the type and succession of wetlands. Thus, an improved understanding of the energy budget of the acrotelm, which is driven by temperature and moisture, would contribute to knowledge of the role of the water table.

17. The role of evapotranspiration in influencing water budget: Evapotranspiration is the most poorly understood element of the water budget of wetlands. More knowledge of the role of evapotranspiration is needed before an adequate understanding of wetland hydrology can be achieved.

18. The role of the plant community in evapotranspiration: It is well known that large quantities of water are transpired by plants during photosynthesis. However, the precise role that plant transpiration plays in influencing the water budget of wetlands is not well understood.

19. Recharge and discharge dynamics of wetlands as influenced by landscape features: Local topography can greatly influence the recharge and discharge dynamics of wetlands. For example, isolated, perched wetlands can respond quite differently during low flow periods than low-lying wetlands (Boelter and Verry 1977). However, the influence of topography on wetland hydrology is largely unknown, particularly on a regional scale. This information need is related to several of those discussed in the previous section.

ECOSYSTEM INTERACTIONS

Linkages between Geochemistry and Hydrology

Few geochemical processes in wetlands, including those discussed in the preceding section on "Geochemical Processes", operate in isolation from hydrological processes. Similarly, few hydrological processes are uninfluenced by geochemical mechanisms. The extent to which these processes are interdependent is really a matter of degree rather than absolutes. The information needs identified here are based relatively more on linkages between geochemistry and hydrology than the information needs discussed in earlier sections.

Specific information needs on the linkages between geochemistry and hydrology include:

20. The response of water quality to changes in water quantity: Intuitively, one can see how the general quality of water in a wetland is related to its volume of standing and flowing water. Quantitative relationships, however, are not simple. Of particular interest is the impact of water volume changes on the concentrations of metals, dissolved organic carbon, and wetland nutrients.

21. The role of hydrology in retention of organics and metals: As mentioned earlier, the various processes that together substantially alter the chemistry of waters moving through wetlands are not well understood. Although there is a reasonable amount of evidence to support the contention that its role is a qualitatively important one (Jones *et al.* 1986), at present, no direct evidence exists that can be used to quantify the role of hydrology in wetland chemistry. (See also Research Need # 20).

22. Peatland energy-permafrost relationships: Permafrost underlies much of Canada's northern peatlands. The relationship between climate and peatland permafrost is, at best, understood only in qualitative terms.

23. ***Wetland inputs of dissolved organic carbon (DOC) in basin chemistry:*** Wetlands are important sources of organics for other surface waters (Gorham *et al.* 1986). Attempts to predict DOC concentrations in surface waters from the amount of wetland in catchments have, however, yielded mixed results (Kessel-Taylor 1985). This suggests our knowledge of wetland sources of DOC is incomplete. Little is known about the relative contributions of DOC from different wetland types.

Wetland Evolution and Ecosystem Dynamics

Compared to most of the needs listed above, the research and information needs documented below are broad in nature. Each need has many components which could be research studies in themselves. Resolving these broad needs will only be achieved through extensive integrated research efforts.

The research and information needs identified relate to:

24. ***Role of wetlands in long-term ecosystem dynamics:*** The long-term evolution of ecosystems is shaped by allogenic (outside) forces such as geological and climatic changes and autogenic (inside) forces resulting from activities of the living ecosystem components. Much remains unknown about how wetlands change over long periods of time and how they influence changes in terrestrial and aquatic ecosystems.

25. ***Wetland dynamics in the context of terrestrial and aquatic ecosystems:*** This need centres on the relationship of wetlands to the surrounding ecosystems (similar to Research Need #24 above) but is cast in the context of present relationships rather than long-term change.

EFFECTS OF HUMAN ACTIVITY

Wetlands in some areas of Canada are disappearing at an alarming rate due to human activities (Environment Canada 1986, Rubec *et al.* 1988). Loss or degradation of wetlands to-date have mainly been due to drainage and/or infilling, in order to accommodate agriculture, forestry and urban expansion. Over the last two decades, concerns that air pollution and climate change are also contributing to wetland loss have been raised by both the public and private sectors.

In this section, the information needs related to geochemical and hydrological process which must be met to better understand the effects of human activities on wetlands are identified. Such information is essential for developing effective mitigation measures. The information needs defined at the workshop fall into three categories:

- global climate change;
- atmospheric pollution; and
- land use.

GLOBAL CLIMATE CHANGE

Over the next century, the increasing concentrations of radiative-active gases (e.g. CO_2 and CH_4) in the lower atmosphere are expected to alter air temperatures and precipitation patterns in North America (Bolin *et al.* 1986, Jaeger 1988). In central Canada, for example, summers are expected to become drier and warmer, while winters become wetter (Kellog and Zhao 1988). It is difficult to predict and mitigate the potential effects of climatic change on Canada's wetlands because the influence of seasonal and annual climate on wetland structure and function is not well understood. However, various models have predicted major shifts in such biomes as the central Prairie that could have profound effects on wetlands (Rizzo and Wiken, in press).

The climate variables of interest (with respect to the effects of climatic change on wetlands) are air temperature, precipitation, atmospheric CO_2, atmospheric ozone and ultra-violet effects (UV-B).

The research that is needed in order to better understand the effects of climate change on the geochemical and hydrological aspects of wetlands includes:

26. The effects of water table fluctuations on wetland function and integrity: The water table is often the single most important variable governing the function and distribution of wetlands. The degree of contact with the water table determines the wetland type, the wetland's control on local basin hydrology, and its effect on water quality.

The projected changes in seasonal and annual air temperatures ($\approx$ + 4.0 °C in an atmosphere with doubled CO_2) and changes in regional precipitation will affect regional water tables, and consequently, the availability of groundwater to wetlands. Empirical data show that water table depth follows mean annual precipitation (Regier and Meisner 1990). Clearly then, a sound understanding of the role the water table plays in controlling wetlands is important with respect to climate change. Studies are needed to elucidate the influence of the water table on wetland gas dynamics, productivity, decomposition rates, and water retention properties of wetlands.

27. The interaction of temperature and moisture in the unsaturated zone (acrotelm) of wetlands: An improved understanding of the temperature-moisture interactions (i.e. the energy budget) of the acrotelm would contribute to the knowledge of the water table's role in wetland function. More knowledge in this area is important to comprehend wetland response to climate change. (See also Research Need #16 above).

28. The effect of changes in the quantity of water in, or flowing through, a wetland on wetland water quality: Intuitively, the quality of water in a wetland should be affected by changes in its volume of standing water, or by a change in its throughflow. Research is needed to better understand the relationships between water quantity and water quality of wetlands and the sensitivity of different wetland types to hydrologically mediated changes in water quality. Of particular interest is the effect of changes in water volume on the concentration of metals, dissolved organic carbon (DOC), and nutrients. Another area where research is needed consists of determining the importance of aeration on the rooting zone.

29. Effects of permafrost melting: The projected increases in surface temperatures in a "warmer" climate are expected to be greatest at high latitudes due to the positive feedback effect of reduced albedo (Bolin *et al.* 1986). Since groundwater temperature tracks mean annual air temperature (Meisner *et al.* 1988), a warmer climate could cause significant reductions in permafrost. The effect of released frozen groundwater on wetlands and local hydrology is not well understood (e.g. will new wetlands be created, existing wetlands enlarged, or will thermokarst erosion cause the released groundwater to run off the land, resulting in a net loss of moisture?). Concomitant with changes in permafrost are potential changes to the local hydrological regime. The potential effects of large-scale changes in permafrost due to climate change need to be further investigated.

Another potential effect of permafrost melting warrants investigation. Some permafrost contain crystals of water and methane called clathrates (MacDonald 1989). The quantity of methane in these crystals is estimated to be in gigatons. The release into the atmosphere of such methane would provide a positive feedback effect to the "greenhouse effect" and could, in turn, affect wetlands due to the large role of methane in wetland dynamics (Moore 1991).

30. Influence of atmospheric CO_2, temperature, and moisture on growth: The projected changes in regional air temperatures and precipitation patterns in response to doubled atmospheric CO_2 is expected to affect the growth, and ultimately, the distribution of wetlands. While air temperature, precipitation, and atmospheric CO_2 are believed to play a key role in wetland growth and productivity, the mechanisms through which these variables interact with wetlands are not well understood. In addition to influencing basin water quality and hydrology, wetlands also provide habitat for terrestrial and aquatic wildlife (Prince and D'Itri 1985, Rubec *et al.* 1988). Changes in wetland growth and production in response to climate change will undoubtedly affect the wildlife populations that are dependent upon them for habitat. Research is needed to identify the mechanisms by which these variables elicit control on wetland growth, distribution, and dependent wildlife.

31. Response to changes in fire frequency and intensity: Regional changes in precipitation and seasonal air temperatures (due to climate change), are expected to significantly increase the frequency and magnitude of forest and grassland fires in the boreal forest zone of Canada (Harrington 1989). Relatively little is known of the role natural burn-overs play in wetland function. Do wetlands require these periodic events? Are different wetland types equally tolerant of changes in fire frequency? More research on the role of fire in wetlands is needed to better understand and prepare for climate change. Studies of the response of Canadian wetlands to past fire regimes would provide insight into the sensitivity of wetlands to fire.

32. Adaptiveness of wetlands to climatic change: Wetlands, like other ecological systems, have evolved in a dynamic physical environment. The current belief is that wetlands, especially those along shorelines, depend on relatively large seasonal fluctuations in water availability and temperature to maintain their inherent structural diversity (Keddy and Reznicek 1986). The regional distributions of wetlands are also thought to be governed by climate, but it is difficult to predict how climate change will impact wetlands. Different types of wetlands (e.g. bogs and fens) may respond differently and/or vary in their sensitivity to permanent and large-scale temperature and moisture changes. One important information gap that exists concerns the effects of climate change, for each locale, on the natural successional trajectory of fen to bog. Will climate change be too fast to ensure ecosystem integrity?

ATMOSPHERIC POLLUTION

The local and long-range transport of air pollutants is one component of global environmental change that is believed to be affecting Canadian wetlands. Of particular concern is the deposition of sulphur and nitrogen oxides, metals, and organic contaminants such as insecticides.

Specific concerns associated with atmospheric pollution are described by the following research needs:

33. Effects of nitrogen deposition on the retention and release of nitrogen by wetlands: Little is known about the effects of increased concentrations of atmospheric nitrogen on wetlands. Of particular interest are the potential effects of nitrogen on the acidification and eutrophication of wetlands. Because nitrogen is one of the primary limiting nutrients for plant growth, the implications of the anthropogenic increase in its availability to wetland flora requires investigation.

34. Long-term fate of sulphates, metals, and organic compounds in wetlands: Wetlands act as sinks for airborne metals and organic substances. However, the fate and effects of deposited sulphate, associated hydrogen ions, metals, and organics on different wetland types is not well understood. The interaction of these substances with the DOC of wetlands also requires investigation. For example, pulsed releases of sulphur in the spring or after heavy precipitation events are believed to contribute to episodic depressions of pH in downstream surface waters. These local acidification events are, in turn, suspected to affect DOC and metals in wetlands.

Many issues need to be addressed to better understand the effects of long-range transport of air pollutants on wetlands. For example, what is the role of the solid phase (peat) in retaining such pollutants by absorption or complexion? Does DOC enhance discharge of these substances from wetlands? Is the quality of DOC of wetlands being altered due to the influx of these pollutants?

35. The effect of wetland hydrology on the storage of airborne pollutants: In addition to studying the effects of air-transported metals and organic compounds on wetlands, research is needed to elucidate the effects of wetland hydrology on the fate of these substances. It is not fully understood how the hydrology of different wetland types affects the activity and retention of these pollutants. More research is needed to determine the role of wetlands in regulating the retention and release of deposited contaminants.

36. Influence of acidic precipitation on wetland function and water quality: Changes in wetland pH due to acid precipitation likely affect the function and water quality of wetlands (Gorham *et al.* 1984). Depressed surface water pH mobilizes metals that are bound out of solution. It is suspected that acidic precipitation is causing the release of metals and other substances (that are normally bound at higher pH) to surface waters. Of particular interest is the release of harmful metals such as aluminum. While peat itself does not contain much aluminum (only what comes in via air and water), there is some concern that drinking water supplies derived from areas with a high concentration of wetlands may be contaminated by accelerated release of deleterious substances from wetlands. DOC may also be affected by acidic precipitation; a fact which would thereby alter wetland function. More basic research is needed to better understand the acid-base properties of wetlands, the issue of surface water contaminants, and the role of DOC.

Little is known of the relative sensitivity of wetland types to acid precipitation (Kessel-Taylor and Anderson 1987). Of special concern is the sensitivity of poor fens (Gorham *et al.* 1987). Hence, studies need to be undertaken to assess the sensitivities of all wetland types to acidic precipitation.

LAND USE ACTIVITIES

The third major category of human activity is comprised of the activities that affect wetlands directly. These include activities such as those associated with agriculture, forestry, industry, urbanization and road building. While the focus of this section is on the effects of human activity on wetland geochemistry and hydrology, the link is also made between physical and chemical effects and terrestrial and aquatic wildlife habitat. Of concern are both the direct effects of these land use activities on wetlands, and the indirect effects of modified wetlands on adjacent and downstream areas.

The general land use activities of concern to wetlands in Canada are:

• Agricultural Development
- drainage practices
- land clearing
- seasonal exploitation
- fertilizer use

• Urban Development
- housing and industrial construction
- fill disposal
- industrial effluent

• Harvesting
- peat horticulture
- peatland and hardwood forestry

• Impoundments
- hydroelectric reservoir flooding
- river corridor drainage and flooding

• Prescribed Burning

• Roadbuilding
- rural agricultural areas
- major highway corridors

Research and information needs are focused on:

37. Effects on water table: Long-term regional studies which investigate the effects of land use on surface water quality and hydrology are needed. Information from such studies will be useful for developing mitigative strategies for future development in unaffected areas. Of particular concern are the activities of filling and draining wetland areas, and the effects of land clearing. These activities are suspected to have far-reaching effects on wetland water quality and hydrology.

Changes to water availability and local hydrology will affect surface water quality both within and downstream of wetland areas. Wetland areas may act as either or both discharge and recharge sites for regional water tables; thus, impacts on wetland surface water quality and hydrology may also impact water table levels and water quality. Similarly, because wetlands are dependent upon water table height and quality, land use activities which affect the water table in upland areas may also affect wetlands in areas below the activity through effects on surface waters and the water table. Water resources in lower basin areas may be affected by permanent changes in upper basin hydrology. Changes to basin hydrology affect both the magnitude and frequency of flooding in lower basin areas, as well as the amount of water available for recharge during dry periods.

38. Cumulative effects on wildlife resources: Land use practices which physically alter wetland areas directly affect the wildlife that depend on wetlands for part or all of their life cycles. Waterfowl and fisheries resources, as well as some furbearers, are especially vulnerable to wetland habitat loss or impairment. The effects of land use practices on the structure and distribution of wetlands are relatively easy to detect compared to their indirect effects on wildlife populations.

Wetlands, especially those along shorelines, are an integral component of the structure of aquatic communities. They are considered to be centres of ecological organization for fish communities (Steedman and Regier 1987). Wetlands are used for reproduction, early rearing, feeding and protection by aquatic and terrestrial wildlife. It has only been recently realized that wetland losses over the decades have caused permanent changes in the structure of aquatic communities. Wetland areas also comprise the critical ecotone between terrestrial and aquatic environs. It is these areas that exert profound, yet not well understood, controls on ecosystem resiliency and health.

39. Long-term response to agricultural development: Studies are needed to investigate the effects of agricultural development on prairie wetlands (particularly the effects on structure and distribution of prairie potholes and the wildlife that depend on them). Studies are also needed to assess the resiliency of these ecosystems to various seasonal agricultural practices such as fertilization, tillage, planting, and harvesting.

40. Response of wetlands to urban runoff: Wetlands are often used as drainage areas for storm sewer-water discharge points, especially in areas where an urban centre is adjacent to a large river or lake. Studies are required to determine the fate and effects of contaminants originating from urban runoff on wetlands and wildlife.

41. Efficacy of "no net loss" policies: Some current policies (e.g. the Department of Fisheries and Oceans' 1986 *Policy for the Management of Fish Habitat*) require developers to replace any wildlife habitat destroyed through development so that "no net loss of habitat productivity" occurs. This habitat may be reconstructed at that site or elsewhere. The effectiveness of such policies for wetlands and wildlife habitat needs to be investigated. Long-term post-development monitoring is necessary to determine whether "like for like" can actually be replaced in other locales. The role of "no net loss of wetland functions" policies (e.g. *The Federal Policy on Wetland Conservation* adopted in 1991) in altering the impact of development and natural resources allocation decisions needs consideration by researchers.

Adequate replacement is highly improbable for peatlands that have developed through complex successional processes over thousands of years, particularly where landscapes have become strongly patterned as a result of delicate interactions between vegetation and hydrology (see Glaser *et al.* 1981, Janssens *et al.* in press).

WETLAND HABITAT

Wetlands are distinct from the upland and aquatic ecosystems that surround them. They provide essential habitat to many vertebrate, invertebrate, and plant species (National Wetlands Working Group 1988, Gorham 1990). In this workshop, four information and research areas that would provide valuable information for managing wetland habitat were identified:

- ecological dynamics;
- limiting factors affecting the distribution of organisms;
- wetland interactions with other habitats; and
- wetland restoration and preservation.

ECOLOGICAL DYNAMICS

The processes that affect the condition of wetland habitat and the capability of wetlands to support wildlife were the main concern. These are:

- the carbon, nitrogen, phosphorus and sulphur cycles;
- population dynamics of plants and animals that control biodiversity (invertebrate dynamics in particular); and
- wildlife response to altered hydrology, and to other wetland habitat changes.

The Carbon, Nitrogen, Phosphorus, and Sulphur Cycles

The element cycles define the structure of wetland habitats. They are important factors in the growth and stability of plant, invertebrate and vertebrate populations. The discussion focused on these attributes of the element cycles, and included the indirect influence of the element cycles on the rate of peat accumulation and subsequent effects on wetland habitat structure.

The research associated with the cycling processes should:

42. Identify the relationships between the carbon, nitrogen, phosphorus and sulphur cycles and the success of plant, invertebrate and vertebrate populations: There is an outstanding need to further explore the cycling processes of carbon, nitrogen, phosphorus and sulphur in Canadian wetlands. This need is especially pronounced in southern freshwater wetlands and northern peatlands. Such studies should include investigation into important below-ground processes that involve the microbial actions that influence element cycling processes.

There is also a clear need to determine the role of the element cycles in the population dynamics of wetland wildlife. The quality of habitat, in terms of its ability to support vegetation, invertebrates, and vertebrates is intricately tied to the element cycles. Because the first two population types are the food source for many vertebrate species of wildlife, the success of these prey species is vital. An improved understanding of these cycles will allow researchers to determine the relationship between wetland biodiversity and element cycling processes.

43. Within the carbon cycle, determine how the rate of peat accumulation affects habitat structure: The carbon cycle is known to be an important component in the production of peat. Because peat is a significant factor in defining the habitat structure of wetlands, the role of the carbon cycle in peat growth and accumulation must be studied further.

Population Dynamics of Plants and Animals

Discussion explored how wildlife use wetland habitats and how habitat use by one species affects habitat use by another. The role of invertebrates in the wetland food chain was also identified as an area dominated by significant gaps in information.

The specific research areas that were identified are:

44. Link wetland characteristics to wildlife and determine which species prefer which types of wetlands: Resolution of Research Need #42 will indicate which prey species will be present in particular wetland habitats. This information can then be used to identify which predator species should also be present in that wetland habitat. In addition, the structure of wetlands, in terms of shape, vegetation cover, and amount of peat, will directly influence the species of wildlife that are present.

45. Define the interactions that occur among wildlife species: Investigations are required to document and explain the wetland food chain and, in particular, determine why certain species are dominant in particular types of wetlands; why certain species are transient in particular types of wetlands;

and why rare and threatened wildlife thrive only in particular wetland types.

46. Examine invertebrate interactions with predators and with wetland geochemical and water flow processes: The invertebrates anchor the food chain and are, therefore, extremely important as a food source. It is the diversity of invertebrate life in a wetland that draws the diversity of predators to wetland habitats. The invertebrates are strongly tied to vegetation chemistry and water flow regimes in wetlands and are stressed by disturbances of them. Invertebrates, therefore, have utility as bio-indicators of wetland disturbance. Resolution of the information and research needs on geochemical and water flow processes will elucidate information that can be used to investigate which wetland processes are tied to invertebrate population dynamics.

Wildlife Response to Alterations in Hydrology and to Other Changes in Habitat

Wetland disturbance can produce many dynamic system alterations, including: changes in species composition; alteration and loss of structure or function; and destabilization of interactions with other ecosystems in the biosphere (Gorham 1990). In all cases, the disturbance may be generated from natural or anthropogenic sources, although the anthropogenic changes often cause more severe effects.

As direct human disturbances increase (e.g. draining, damming, hydro projects, pollution, forestry, agriculture, etc.) and natural disturbances become less predictable owing to indirect effects of human activities (e.g. global warming, chemical interactions resulting from pollution sources) an understanding of the effects of wetland disturbance becomes indispensable.

Before we can manage wetlands for disturbance scenarios, we need to understand:

47. How various species of wildlife respond to wetland alterations at a series of levels: This is a large and complicated issue that must address the alteration of different habitat components (e.g. change in vegetation structure, change in food source, altered pH, etc.) from the molecular level to the ecosystem structure level. An understanding of how different wildlife respond to the disturbance of different habitat attributes at different levels of resolution will allow managers to predict the effects of disturbance regimes in wetlands.

48. Indirect interactions must also be explored: Although a disturbance may not directly affect a predator species, it may produce an indirect effect by stressing the prey species that it feeds upon. These dynamic food chain associations should be documented.

LIMITING FACTORS AFFECTING THE DISTRIBUTION OF ORGANISMS

Discussion of those factors which limit the distribution of organisms also focused on those which limit their abundance and productivity. These limiting factors were identified as:

- precipitation and temperature;
- nutrients;
- acid/base balance and salinity;
- hydrology; and
- species interactions and wetland size.

Precipitation and Temperature

Although wildlife are adapted to "normal" variations in atmospheric conditions, they can be sensitive to extreme events which lead to unusual disturbances in the habitat processes. Research is required to:

49. Identify how atmospheric events make wetland habitats unsuitable or limiting to wildlife: Weather events may limit the suitability of habitat for a particular species and, in turn, limit the distribution, abundance, and productivity of wildlife. The effect of habitat alteration for a particular species is dependent upon that species' unique tolerance to habitat changes. Weather-related factors that limit habitat suitability are:

- residence time of snow packs;
- amount of sunlight received;
- length of growing season; and
- variation between the diurnal minimum and maximum temperatures.

Studies should investigate the reasons why a habitat becomes unsuitable for sensitive species after a significant atmospheric event.

Nutrients

The survival of invertebrates and plants is dependent upon the availability of prerequisite nutrients. Studies must, therefore, be conducted to determine:

50. The minimum nutrient requirements for selected plant and invertebrate species in various wetland types: Because the availability of nutrients affects the health and vigour of plants and invertebrates, any process that limits the supply of essential elements and minerals will affect the ability of these wildlife to survive.

Acid/Base Balance and Salinity

How fluctuations in pH and/or salinity may limit habitat suitability for wetland wildlife was considered. The associated research need is:

51. Determine how various wetland types with specific acid/base and salinity characteristics limit wildlife habitat suitability and consequently, the survival of specific wildlife species: Although the acid/base balance and salinity characteristics primarily limit plants and invertebrates, they may also influence habitat suitability for vertebrates (e.g. amphibians and some waterfowl). Many species have very specific pH, DOC and salinity requirements and are, therefore, absent from any wetland habitat that does not meet these requirements.

Hydrology

Hydrology was discussed not as a process but as a component that may limit habitat suitability. Different wetland habitats have different characteristic flow regimes which, in turn, dictate the suitability of habitat for wildlife. Research should address:

52. *How various wetland types with specific flow characteristics limit wildlife habitat suitability:* The nature of the flow (e.g. velocity, volume, depth below the surface, water table fluctuations, etc.) and the nature of water levels were identified as the major hydrological factors influencing the suitability of a wetland habitat for wildlife.

Species Interactions and Wetland Size

This section of the workshop addressed those factors that promote the dominance of a particular wildlife species in a wetland habitat. While it was recognized that dominance is the result of many dynamic variables, it was addressed at the simplest level. Firstly, the relationship between habitat size and the success of a species was considered. Secondly, the interactions that occur between species in a wetland habitat to determine how one species out-competes another were investigated. Research must, therefore, consider:

53. *How the dominant wildlife species in a wetland habitat maintain their dominance at the large and small vertebrate level, plant level, and invertebrate level:* This discussion is intricately linked with the above section on "Population Dynamics of Plants and Animals" (Research Needs #45 to #47). It addresses how the presence of certain species in a wetland habitat will limit or restrict the colonization by other wildlife. The dynamic interactions among wildlife species have not been studied as fully for wetlands as they have for many other upland habitat types. It should be noted that the issue is vast with many components and must, therefore, be tackled piece by piece over an extended period of time.

54. *Determine minimum area requirements for wetland wildlife:* A factor that could have a substantial impact on habitat suitability is the size of the wetland. Many larger vertebrate species have minimum area requirements and are only dominant in those habitats that meet these requirements.

WETLAND INTERACTIONS WITH OTHER HABITATS

Many upland and aquatic habitats surround, influence, and interact with wetlands. As a result, it is important to investigate how these surrounding habitats affect wetlands and whether the effects are predictable.

In general, the two broad categories of "other habitats" discussed were natural habitats and anthropogenic habitats (habitats created or altered through human use). The issues that emerged from the discussion of natural habitats include:

- upland habitats;
- aquatic habitats; and
- atmospheric influences.

The discussion of anthropogenic habitats focused primarily on how human disturbances in neighbouring habitats has:

- affected the processes in the wetlands;
- led to the inflow of unusual quantities of nutrients; or
- increased contaminant levels.

The issues discussed include:

- drainage alterations;
- habitat alteration and land use change;
- waste water; and
- atmospheric and stream deposition.

Natural Habitats

Consideration was given to how the inputs (water, nutrients, toxins and biota) from upland and aquatic habitats affect wetland ecosystems. It is also important to define the nature of the outputs from the wetland to surrounding habitats and to determine whether the type of adjacent habitat affects the nature and composition of that output. A great deal of knowledge needs to be gained to help explain how different habitat types interact with wetlands.

The research needs are to:

55. *Identify the variety of wetland habitats that exist in Canada and define how their characteristics differ:* Different wetland habitats will have different nutrient cycling processes, biota, toxins and flow regimes. This will obviously influence the species of wildlife found in that wetland and, therefore, the wildlife interactions that occur between neighbouring habitats. Documentation of how wetland habitat types differ will help explain wildlife presence/absence and species interactions.

56. *Determine whether particular ecosystem types adjacent to a wetland affect the wetland's outputs and internal processes:* A need exists to identify how different upland and aquatic habitats affect wetland output and influence wetland processes.

57. *Determine what form of precipitation most significantly affects wetland processes (e.g. fog, thunderstorm, snow, etc.) with respect to water levels and chemical inputs and determine whether the type of atmospheric event and intensity of the event affect wetland processes:* Atmospheric water and chemical inputs must be identified and linked with the wetland processes that may be affected. If atmospheric inputs play a role in wetland processes, research must be conducted to determine the significance of the form of precipitation.

Human Induced Drainage and Habitat Alterations

Activities such as agriculture, forestry, peat harvesting, hydro projects, and road building can greatly affect natural flow regimes and, therefore, alter the flow of water into the wetland. The use of machinery, the removal of native vegetation, and extensive land management are the primary mechanisms that influence flow from disturbed habitats.

Research (including diverse experiments on natural wetlands) should:

58. Develop a rudimentary understanding of how particular land use activities adjacent to wetlands affect water inflow rates into the wetland: Human activity will directly alter the structure of, and processes in, the habitat where the activity occurs. It may also indirectly disturb nearby habitats. Obviously, the nature of habitat alteration is a function of the land use activity. A discussion of wetland habitat alteration and research needs is presented in the above section on "Wildlife Response to Alterations in Hydrology and and Other Changes in Habitat" (Research Needs #47 and #48).

Atmospheric and Stream Deposition

There is considerable concern about the pollution of wetlands through atmospheric or terresrtial effluent discharge. Pesticides used in forestry and agriculture and the airborne pollutants from industrial sources make their way into even the most remote wetland. In addition, the removal of vegetation through forestry and agriculture often leads to increased sediment loading in streams that flow into wetlands.

The areas of research that are needed are:

59. Determine how the most common chemical pollutants interfere with "normal" wetland processes: How do pollutant induced changes to wetlands affect habitat characteristics such as pH, DOC, nutrient loads, and plant, invertebrate, and vertebrate composition?

60. Determine how increased loads of dissolved solids and sediments affect wetland processes and how this influences the vegetation communities within a wetland habitat: This research need examines whether vegetative growth and survival rates are affected by altered element cycling processes, altered pH and DOC levels and/or the changed water flow properties that may be associated with increased sediment loading.

WETLAND RESTORATION AND PRESERVATION

Given that wetlands are a unique, dynamic and essential habitat to many wildlife species, research efforts must be devoted to restoration and preservation issues. The issues that were flagged as most important to this discussion include:

- understanding wetland successional trends in order to identify valuable wetland sites; and
- the development of wetland restoration technology.

Wetland Succession

It is reasonable that the most valuable (in terms of unique properties and importance to wildlife) wetlands should be protected first. However, until it is determined at which point in the successional cycle wetlands are the most valuable to wildlife, it is difficult to be certain which wetlands are, or will be, important as habitat. The research task is:

61. Through the use of chronosequences and paleoecology techniques, develop an understanding of the successional trends of wetlands and document which stages of succession are the most important to the different wildlife species: This task will require construction of successional pathways for wetland habitats and association of wildlife with a habitat that is at some definable point in its successional path. This, in turn, will allow managers to determine which successional stages are preferred by the species of concern.

In this connection, analysis of fossil bryophytes in dated peat cores now permits the construction of depth and age profiles for inferred pH and height of the peat surface above the mean water table (Janssens 1990, Janssens *et al.* in press).

Wetland Restoration

As wetland loss becomes more of a concern, knowledge of how to restore disturbed wetlands becomes invaluable. Restoration is a tricky science that requires an understanding of which components of a disturbed wetland need to be restored to achieve a desired result.

Caution should be exercised during restoration activities to ensure that the restoration is actually "improving" the wetland and not destroying it. In order to identify which habitat components have been altered and which must be restored, a thorough understanding of wetland habitat processes is essential. Therefore, research must:

62. Develop the ability to predict how particular disturbances will influence a wetland system and develop effective technologies that will restore wetland processes: Experimental ecosystem manipulation must be conducted in order to identify how drainage regimes, acid/base balances, energy balances, and nutrient cycles may be disturbed and restored. As restoration technologies are developed we must also acquire an ability to predict exactly how wetland processes and interactions will be altered in response to various disturbance regimes. We will never be sure that restoration is successful until it is proven through experimentation that geochemical and wildlife processes can be manipulated to a predictable point.

RECOMMENDATIONS

The information and research needs identified in the previous sections result from a broad, but brief examination of issues and ongoing work on wetlands in Canada. The most efficient way of providing the needed information is by taking an integrated approach to research rather than conducting a series of independent research and monitoring efforts. Similar broad and integrated management approaches need to be adopted to deal with the inter-related nature of the suite of problems facing wetland and environment managers.

Each of the following eight recommendations made at the workshop generally relates to one of two types of activities needed to support research on wetland ecology, management and restoration:

- developing infrastructural and organizational services and capabilities; and
- developing inventory, monitoring and research tools and mechanisms.

Although these categories of activities are not entirely discrete, they do form a useful framework for discussing the recommendations.

INFRASTRUCTURAL AND ORGANIZATIONAL RECOMMENDATIONS

1. Develop effective policies nationally for protecting wetlands: Wetlands are being lost at a tremendous rate in some parts of Canada. Losses are particularly high where there are urban and agricultural land use pressures that compete with the maintenance of wetland habitat. Policy is needed for the specific purpose of protecting wetlands. Formal cooperation of the Provinces and the Federal Government must occur before such policy can be successfully implemented.

2. Establish a formal network to coordinate wetlands research in Canada: Although high-quality wetland research is being done in Canada, the overall advancement of knowledge could proceed more efficiently if efforts were more coordinated. A formal network comprised of scientists from university, government and private sectors should be formed to oversee the coordination of research efforts. It should be responsible for developing research priorities, and organizing regular symposia and training sessions. Such a network would have the advantage of ensuring that communication is maintained and that researchers are informed of related activities.

3. Develop wetland centres of excellence: The use of academic centres of excellence to facilitate research has proven to be an efficient mechanism for other scientific disciplines. Centres of excellence would provide good training grounds for researchers and would ideally form part of ongoing wetland research and management. The Federal Department of the Environment could be involved in providing management direction and input into determining research priorities. The centres of excellence would assist with developing research direction as well as actually carrying out a good deal of the ongoing research.

4. Establish a subvention grant program for wetlands research: Subvention grants have been shown to be a productive mechanism for accomplishing natural-resource-oriented research. Wetland subvention grants would provide a mechanism for meeting some of the research needs identified in this report, and would also allow the Federal Government to provide significant input into research directions.

INVENTORY AND MONITORING

5. Integrate existing wetland data into comprehensive databases: Much data on many aspects of Canadian wetlands have already been collected. Efficient use of this information is hindered by the fact that most data exist in scores of small and unique databases throughout the country. Greater use of existing information and less duplication of effort could be fostered by creating centralized information facilities. All existing data would not necessarily need to be integrated into one extensive database, but data should be centralized to permit easier and more efficient use. This task should also include the compilation of relevant climate and hydrological variables that may be used to facilitate investigations of the potential effects of climate change on wetland habitat.

6. Develop well-designed monitoring programs: To clearly understand how wetland processes react to disturbances and change over time, long-term monitoring projects must be established. The emphasis in this recommendation is that the programs must be well designed in terms of both statistical framework and landscape representation. The monitoring programs should, where possible:

- be based on representative drainage basins and/or representative wetland complexes;
- be integrated with existing meteorological and pollution monitoring programs;
- include sites that are not affected by human activity so that components of wetlands that are sensitive to climate

variables (e.g. air temperature, precipitation, CO_2) can be monitored;
• incorporate monitoring of non-wetland habitats that influence wetlands (e.g. in adjacent upland areas);
• include assessment of peat reserves; and
• include both unique and exploitable wetlands.

7. Develop ecological and jurisdictional integration of classification systems: At present there are several classification systems in use in Canada that are intended to be used solely for wetlands or that include wetlands along with other ecosystems. The boundaries used in some of these classification systems are political rather than ecological. Different wetland researchers often use different classification systems. The existing disparity of classification systems hampers efforts to integrate data, assess the state of wetland resources, and determine the effects of perturbations on wetland habitat. Effort should be devoted, therefore, to working towards the integration of existing classification systems. This activity may involve one or more of the following:

• assessing the present classification systems;
• developing a hierarchical classification system that would facilitate use at different spatial scales; and/or
• developing or recommending the adoption of a classification system not constrained by geo-political boundaries.

8. Develop a comprehensive wetland inventory: In conjunction with the above activities, a comprehensive inventory of Canadian wetlands should be compiled. This will come about partially through the fulfilment of Recommendation #1 above. It will involve additional effort, however, including:

• the development of an integrated "inventory" database from existing databases; and
• the analysis of existing databases to identify key missing information, and to eliminate the data gaps.

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