CONSERVING WETLANDS IN MANAGED FORESTS

SUSTAINING wetlands

ISSUES PAPER, No. 1993 - 2

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by

Gregg Sheehy

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North American Wetlands Conservation Council (Canada)

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Foreword

From the Canadian Pulp and Paper Association

In April 1992, the Canadian Pulp and Paper Association (CPPA) issued *A Statement by the Pulp and Paper Industry on Wetlands.* The statement recognizes the importance of Canadian wetlands to the environment, and underlines the industry's commitment to recognizing all resource values of wetlands in its forest land management planning and decision-making processes.

But such a statement of intent needs to be backed up by action — action to ensure that the industry improves its knowledge of wetlands and the effects of forestry activities, and that this information reaches those who can effect forest practices based on this scientific foundation.

The sponsorship of this project will help the industry fulfil its commitment to sustaining wetlands. This report provides an introduction to wetland-forestry interactions. It will assist land managers to pursue wetland conservation in their forestry operations. The paper describes the potential impacts of forestry operations on wetlands and presents a variety of wetland-compatible forestry practices.

The CPPA is proud to be a partner in this venture, along with the Canadian Wetlands Conservation Task Force, the National Round Table on the Environment and the Economy, the federal-provincial Northern Ontario Development Agreement, (Northern Forestry Program), and the North American Wetlands Conservation Council (Canada). Such coordinated, cooperative efforts involving all stakeholders are the key to realizing wetland conservation in the context of sustainable development. The CPPA and its member companies will continue to work with government agencies and wetland conservation groups to incorporate the wise use of wetland resources in their forest management activities.

Acknowledgements

Many people contributed their time and expertise to the research and preparation of this paper. Particular thanks are due to Kenneth Cox of the Canadian Wetlands Conservation Task Force and Jean-Pierre Martel of the Canadian Pulp and Paper Association for their direction throughout the course of the project. John Jeglum and Art Groot of Forestry Canada provided essential background information and valuable advice in reviewing the draft paper. Abitibi-Price Inc. (Iroquois Falls, Ontario), Corner Brook Pulp and Paper Limited (Corner Brook, Newfoundland) and REPAP Manitoba (The Pas, Manitoba) provided an invaluable on-the-ground perspective on wetland conservation problems and solutions. For their considerable efforts and assistance with field visits to their operations, special thanks are due to Rod Gemmell of Abitibi-Price, George VanDusen and Wayne Brown of Corner Brook Pulp and Paper, and Chris Smith and Doug Taylor of REPAP Manitoba. Thanks also to Hélène Dorval of Domtar for her draft review and advice.

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Summary

This paper describes the nature and importance of wetlands in the forested regions of Canada. It describes potential impacts of forestry practices on wetland ecosystems and suggests measures to prevent or reduce these impacts. A variety of wetland-compatible forestry practices are presented.

Wetlands, some of Canada's most productive wildlife habitats, provide numerous economic benefits. The term "wetland" is used to describe areas which have ground water at or close to the surface all or most of the time. Wetlands are subdivided into five "classes": bog, fen, swamp, marsh, and shallow open water. Swamps have the greatest potential for forestry. In Canada, most of the wood harvested from swamps is black spruce. Other commercially important species include tamarack and eastern white cedar. With drainage, or drainage and fertilization, the forestry potential of many treed wetlands can be improved. However, the costs of forest drainage works can be significant, and the practice has not been extensive in Canada.

Two broad categories of forestry activity may affect wetlands: operations on wetland sites, and upland operations near wetland areas. Harvesting is the dominant forestry activity in wetlands. It is potentially damaging due to the sensitivity of wetland sites to damage by machinery and the resulting inhibition of regeneration. Upland logging operations can result in water quality effects on wetlands.

Forest access routes—roads and skid trails—can have the most extensive impacts in both upland and wetland forestry. Roads that cross wetlands frequently block drainage. The common result is flooding on the upstream side of the road with subsequent killing of woody vegetation and partial drying of the downstream area. Roads on wet sites may require extensive preparation of the road bed, with a variety of measures to handle drainage.

Draining wetlands can have a range of effects depending on the extent and intensity of the drainage works. These include: depletion of nutrients on the site, disruption of the natural runoff regime, and impaired water quality in adjacent streams or lakes.

Forestry agencies and forest product companies in a number of jurisdictions have developed measures to deal with wetland conservation concerns. These include new silvicultural measures to reduce disturbance of wet sites, road construction techniques to maintain drainage and control erosion, and forest management approaches which integrate wildlife conservation measures with timber supply. Research and development efforts in a number of areas are improving the ability of companies to carry out forestry operations that are wetland-compatible.

This study recommends a number of measures for wetland-compatible forestry:
(1) *Good road construction,* with adequate provision for drainage and revegetation of roadsides susceptible to erosion.
(2) *Site classification systems* for wetlands, which identify site types with predictable responses to silvicultural treatments, expanded into the non-commercial forested wetlands and the open wetlands.
(3) *Careful planning of harvesting operations,* using good site-type information.
(4) *Winter logging* to minimize site damage. Where summer wetland operations are unavoidable, site-specific information should be used to select the least fragile sites, and low ground-pressure equipment should be used.
(5) *Programs to inform* industry planning and operations staff of the values of wetlands so that they may consider these values in cutblock design, block layout and harvest supervision.

(6) *Training for equipment operators*, to recognize sensitive sites and avoid damaging practices.

(7) *Development of special expertise* by the forest industry, to ensure that wetland values are incorporated effectively in planning and executing forestry operations.

(8) *Cooperative habitat conservation efforts* involving industry, government agencies and conservation groups.

(9) *Research and development* in the areas of low ground-pressure equipment and careful logging.

(10) *Codes-of-practice and guidelines* that include wetland conservation considerations adapted for specific regions in Canada.

(11) *Design of shoreline buffers and filter strips* which consider the characteristics of individual sites rather than following strict guidelines for the width of reserves.

(12) *Further environmental assessment of forest drainage proposals*, as a tool for identifying and alleviating the impacts of forest drainage.

Introduction

Wetlands, some of Canada's most productive wildlife habitats, provide numerous economic benefits. They are home to hundreds of thousands of waterfowl; provide recreational benefits such as hiking, bird-watching, and photography; help maintain the quality of our lakes, rivers and drinking water supplies; and provide timber worth more than $500 million per year to industrial production (National Wetlands Working Group 1988).

Canadians are becoming increasingly aware of the importance of these areas and of the need to accommodate wetland concerns in land management decisions. The forestry sector manages private and public lands which include extensive wetland areas; forest land managers should become familiar with the different types of wetlands and be aware of the special conservation needs of these sites.

Wetlands cover 14% of Canada, or 127 million ha. Boreal peatlands, which include forested and partially treed areas, comprise about 70% of the nation's wetlands (Canadian Pulp and Paper Association 1992). The distribution of wetlands in Canada is primarily determined by climate and landform. Where water inputs from precipitation exceed losses from evapotranspiration, and topography and soil conditions restrict movement of runoff or groundwater, wetlands may develop. The greatest concentration occurs in a belt from northwestern Quebec across central Manitoba and Saskatchewan to northern Alberta and the Mackenzie Valley (Figure 1).

This paper describes the nature and importance of wetlands in the forested regions of Canada. It describes potential impacts of forestry practices on wetland ecosystems and suggests measures to prevent or reduce these impacts. A variety of wetland-compatible forestry practices is presented; these are practical measures currently used in Canada and other countries.

The research for this paper included visits to the operations of three forest companies within the Canadian boreal forest. The Boreal Wetland Region (Figure 2) was chosen as the focus because it contains the majority of Canada's wetlands and is the largest area of commercially accessible forest land (Haavisto *et al.* 1988). The companies, Abitibi-Price in Iroquois Falls, Ontario, Corner Brook Pulp and Paper in Corner Brook, Newfoundland, and REPAP Manitoba in The Pas, Manitoba, were selected because all have significant wetlands within their operating limits. Each has taken specific measures to address wetland conservation concerns.

This is not an exhaustive study of wetland-forestry interactions, nor is it a comprehensive assessment of the impacts of any company's operations. The objective is to identify workable solutions to conservation problems through discussion with knowledgeable industry representatives.

Although the issues highlighted in this paper are particularly applicable to the Boreal Wetland Region, they also apply to many other parts of the country. Wetlands are broadly distributed throughout Canada, and forestry operations in any province or territory could have implications for these important habitats. Thus the impacts and remedial measures described in this report should interest forest land managers concerned with riparian wetlands in the mountains of Alberta and British Columbia, estuaries and marshes on the east and west coasts and the hardwood swamp forests of southern Ontario.

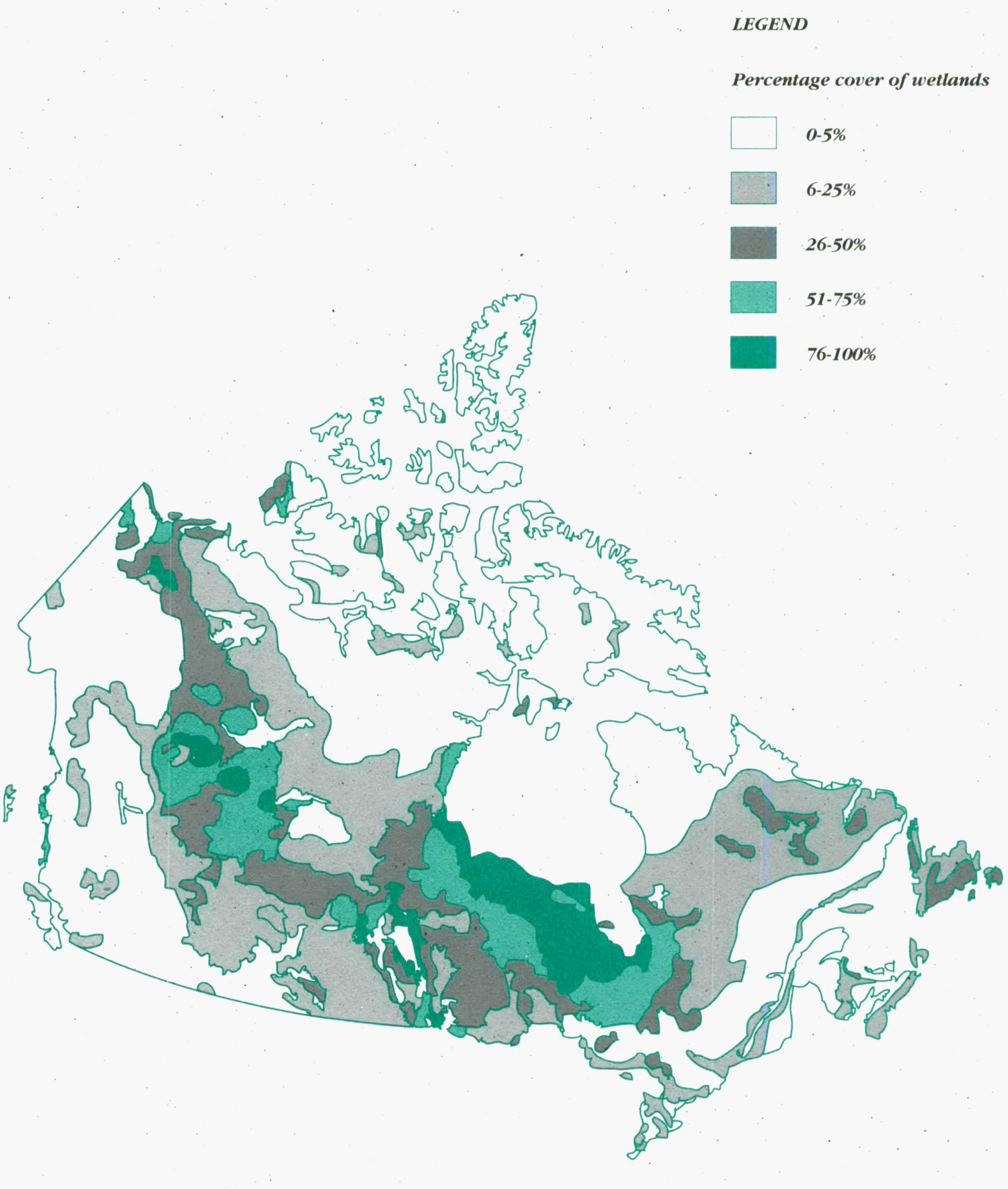

Figure 1 - Distribution of Wetlands in Canada

Source: National Wetlands Working Group (1986).

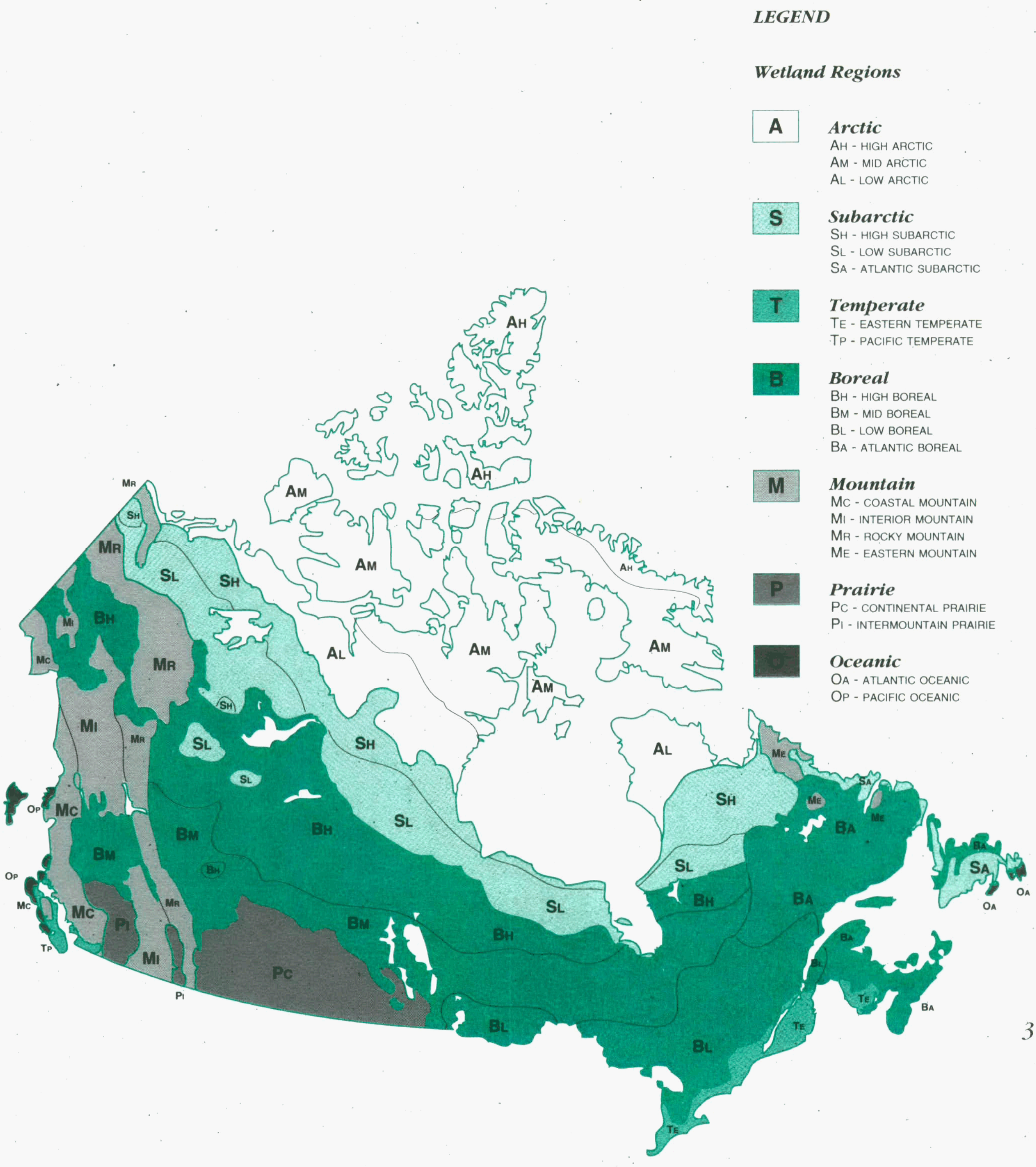

Figure 2 - Wetland Regions of Canada

Source: National Wetlands Working Group (1986).

Wetlands in Canada's Forests

What is a Wetland?

The term "wetland" is used to describe land that is saturated with water long enough to promote wetland or aquatic processes (National Wetlands Working Group 1988). A "peatland" is a wetland on which 40 cm or more of organic material has accumulated. Accumulation of peat can occur when climatic and other physical conditions result in a rate of production (growth) of plant materials such as mosses, reeds, or sedges which exceeds the rate of decomposition. About 90% of the wetlands in Canada are classed as peatlands (National Wetlands Working Group 1988).

Wetlands are dynamic ecosystems which continue to evolve and change over time. In Canada, wetlands have developed since the retreat of glacial ice about 10 000 to 12 000 years ago. The rate at which wetlands evolve is controlled by a complex interaction of climatic, biological, hydrological and related factors.

Wetland Development and Classification

Wetlands are subdivided into five "classes": bog, fen, swamp, marsh, and shallow open water. Definitions of these terms and methods for wetland differentiation have been developed for Canada by the National Wetlands Working Group (NWWG) (NWWG 1988). Each of the five classes can be further subdivided into various "forms" based on landscape, hydrological and other physical factors and "types" related to vegetation characteristics.

In the initial stages of wetland development, when vegetation obtains its nutrients from soil and groundwater, a wetland is termed "minerotrophic". All marsh, swamp and fen communities are minerotrophic, with conditions ranging from high base rich and high pH to low base rich and low pH. This range of rich to poor conditions results in a range of plant species numbers, usually higher in rich environments, and lower in poor.

In peatlands, as the organic layer accumulates, access to nutrients in the underlying soil is reduced and the vegetation must obtain its requirements from groundwater seepage. The type of vegetation and the diversity of species tend to reflect this change in nutrient regime. Plants such as mosses (*Sphagnum* spp.) and sedges (*Carex* spp.) become common and the overall diversity of species becomes lower.

The accumulation of peat can result in the surface of the wetland being isolated from the surrounding mineral-soil influenced groundwaters. The surface vegetation is then virtually unaffected by mineral-soil influenced waters, and it obtains nutrients from precipitation. The wetland is termed "ombrotrophic" and includes plants such as mosses (*Sphagnum* spp.), sedges (*Carex* spp.), and low, ericaceous shrubs. The diversity of species tends to be low, presumably due to the acidic, low base cation environment. Such conditions are typical of the "bog" class of wetlands.

Trees are commonly found in the bog, fen and swamp classes of wetlands but most marsh and shallow water wetlands are treeless across Canada.

A detailed discussion of wetland classification is presented in *Wetlands of Canada* (NWWG 1988). A brief summary of the major wetland classes is presented below.

Bog

An ombrotrophic peatland (dependent on nutrients from precipitation and air) with the water table at or near the surface. Bogs may be open or treed. Vegetation species tend to show a limited diversity due to the acid, nutrient-poor environment with *Sphagnum* mosses and ericaceous (heath-type) shrubs common.

Fen
A minerotrophic peatland with the water table close to the surface. Vegetation may include sedges, grasses, reeds, brown mosses, certain *Sphagnum* species, ericaceous shrubs, medium height shrubs, and trees.

Swamp
A minerotrophic wetland or peatland with standing or gently flowing waters occurring in pools or channels. The water table is usually at or close beneath the surface. The vegetation is characterized by a dense cover of deciduous or coniferous trees or shrubs, herbs, and some mosses.

Marsh
A minerotrophic wetland that is periodically inundated by standing or slowly moving waters. Surface water levels may fluctuate seasonally and vary from fresh to highly saline. Vegetation includes emergent sedges, grasses, rushes and reeds, which may have interspersed areas of open water and aquatic plants.

Shallow Open Water
A minerotrophic wetland that is intermittently or permanently flooded and has open expanses of standing or flowing water. Shorelines, mud flats, shallow lakes, ponds, pools, oxbows, channels and similar features are included in this class. Vegetation, when present, consists of submerged and floating aquatic plant forms.

Riparian zones, areas along stream banks or lake shores, may include a variety of wetland types and are highly productive for wildlife. They provide water, food and cover for many different species and can serve as important travel corridors for larger species (Nova Scotia Department of Lands and Forests - undated). Swamps or treed fens may occur as *basins* surrounded by upland forest.

The major wetland forms that occur in areas of Canada where forestry activity takes place are listed in the sidebar.

Why be Concerned about Wetlands?

Wetlands were once viewed as wastelands—impediments to progress which could only be made useful by drainage and conversion to agriculture or urban development. Canadians are becoming increasingly aware, however, that wetlands have many important functions. Indeed, marshes, swamps, fens and bogs are essential components of the earth's ecosystems. They have their own characteristic roles in natural cycles, distinct wildlife habitats and important economic values.

As elements of a broader landscape, wetlands form important links between uplands and the open water of lakes and streams. They help maintain the natural cycles and life-support systems on which all resource use depends. The effects of degradation or loss of a wetland can have far-reaching effects on the larger ecosystem.

Some wetlands are valued because of their uniqueness, while others are important because of cumulative losses of these habitats over past decades (Bond *et al.* 1992). The more we study wetlands, the more we learn about their ecological, social and economic value. Among the important wetland functions which have been identified are: habitat for numerous species of plants and animals, control of flooding and erosion, protection of surface and ground water quality, recreation, timber production and ecological research (Figure 3).

Canada's Move to Conserve Wetlands

In recent years, wetland values have increasingly been recognized in government and industry policy. Canada signed the Ramsar Convention on Wetlands of International Importance in 1981. Thirty-one Canadian sites have been designated to date, and all provinces and territories are represented in the system. In 1986, the Canadian and United States federal

Main Wetland Forms in Managed Forests in Canada

***Wetlands of Canada* (National Wetlands Working Group 1988) provides descriptions and classification of 70 wetland forms in Canada. The major wetland forms that occur in areas of Canada where forestry activity takes place include:**

- **domed bogs**
- **northern plateau bogs**
- **basin bogs**
- **slope bogs**
- **horizontal fens**
- **basin fens**
- **spring fens**
- **northern ribbed fens**
- **basin swamps**
- **stream swamps**
- **floodplain swamps**
- **delta marshes**
- **shore marshes**
- **floodplain marshes**

FUNCTIONS – (CAPABILITIES)	EXAMPLES OF PRODUCTS, SERVICES AND EXPERIENCES SUPPORTED BY WETLANDS	EXAMPLES OF BENEFITS TO SOCIETY DERIVED FROM WETLANDS
Life-support		
Regulation/Absorption	Climate regulation, toxics absorption, stabilization of biosphere processes, water storage, cleansing.	Flood control (lives saved, $ saved), contaminant reduction, clean water, storm damage reduction, health benefits, erosion control.
Ecosystem Health	Nutrient cycling, food chain support, habitat, biomass storage, genetic and biological diversity.	Environmental quality, maintenance of ecosystem integrity, risk reduction (and related option values).
Social/Cultural		
Science/Information	Specimens for research, zoos, botanical gardens, representative and unique ecosystems.	Greater understanding of nature — locations for nature study, research, education (field trips).
Aesthetic/Recreational	Non-consumptive uses such as viewing, photography, birdwatching, hiking, swimming.	Direct economic benefits to users' personal enjoyment and relaxation, benefits to tourist industry, local economy.
Cultural/Psychological	Wetland uses may be part of traditions of communities, religious or cultural uses, future (option) opportunities.	Social cohesion, maintenance of culture, value to future generations, symbolic values.
Production		
Subsistence Production	Natural production of birds, fish, plants (e.g. berries, rushes, wild rice).	Food, fibre, self-reliance for communities, import substitution, maintenance of traditions.
Commercial Production	Production of foods (e.g. fish, crops), fibre (e.g. wood, straw), soil supplements (e.g. peat).	Products for sale, jobs, income, contribution to GNP.

Figure 3 - Translating wetland functions into benefits valued by society.

Adapted from deGroot, 1988 and Filion, 1988.

governments signed the *North American Waterfowl Management Plan (NAWMP)* (Environment Canada and U.S. Department of Interior 1986), which focuses on the rejuvenation of waterfowl and other migratory bird and wildlife populations through the conservation of uplands and wetlands. The *NAWMP* will affect over 2.4 million ha of high quality wetland and upland habitat in Canada (NAWMP Committee 1989).

The Government of Canada has adopted the *Federal Policy on Wetland Conservation* (Government of Canada 1991). Goals of the policy include:

- no net loss of wetland functions on all federal lands and waters;
- enhancement and rehabilitation of wetlands in areas where the continuing loss or degradation of wetlands or their functions have reached critical levels; and
- recognition of wetland functions in resource planning, management and economic decision-making for all federal programs, policies and activities.

There are also a number of provincial and local initiatives, such as wetland inventories and evaluation programs (Bond *et al.* 1992). Ontario recently adopted a provincial wetland policy, and Alberta and Saskatchewan are currently developing wetland policies.

In April 1992, the Canadian Pulp and Paper Association (CPPA) released *A Statement by the Pulp and Paper Industry on Wetlands*. The Statement observes that the "pulp and paper industry contributes significantly to sustaining Canada's wetlands by recognizing wetland functions in its forest resource management planning process." Specific measures cited for sustaining wetlands include: winter harvesting of timber from peatlands, using specially-equipped machines; special precautions in planning the location and construction of roads, bridges, and culverts; appropriate studies prior to the drainage of peatlands; and, the application of provincial regulations and guidelines for work in and around wetlands. The Canadian Sphagnum Peat Moss Association (CSPMA) adopted the *CSPMA Preservation and Reclamation Policy* in 1991, while other industries are signalling their commitment to wetlands through conservation projects (Lynch-Stewart *et al.* 1993).

The CPPA Statement cites specific measures for sustaining wetlands: winter harvesting of timber from peatlands, using specially-equipped machines; special precautions in planning the location and construction of roads, bridges, and culverts; appropriate studies prior to the drainage of peatlands; and, the application of provincial regulations and guidelines for work in and around wetlands.

Forestry and Wetlands

Forestry Values and Uses

The swamp wetland class, which occurs on wet mineral as well as organic soils, has the greatest potential for forestry. In Canada, most of the wood harvested from swamps is black spruce. Other commercially important species in swamps include tamarack and eastern white cedar. In addition to the spruce swamps, some areas of treed fen and hardwood swamps are also utilized (Jeglum 1991a).

Precise estimates of the amount of productive forest on wetland sites are unavailable for Canada. However, there are significant areas of partially treed or forested wetlands in most provinces. Black spruce dominated peatlands produce about 20% of all roundwood harvested in Ontario. Wetlands are also significant sources of forest production in other provinces such as Quebec, Alberta and Manitoba (Haavisto and Jeglum 1991).

Most harvesting on wetlands is by clearcutting, with natural regeneration from advance growth (young trees on the site at the time of logging) being the most common method of forest renewal. Natural regeneration is supplemented by planting. Other silvicultural treatments such as thinning, spacing, fertilization and drainage have been limited (Jeglum 1991a).

With drainage, or drainage plus fertilization, the forestry potential of many forested peatlands and wet mineral soil sites can be improved. Many such sites have been developed for forestry in Scandinavian countries. In Canada wetland drainage for forestry purposes has been limited, totalling less than 25 000 ha (Haavisto and Jeglum 1991). Drainage has been most extensive in Quebec, where the province subsidizes these works on private lands. In recent years, some 5 000 ha have been drained annually in Quebec, mainly on clearcut areas on private lands (Trottier 1991b). There is significant potential for increasing timber production through drainage of selected wetlands (Haavisto and Jeglum 1991).

Two broad categories of drainage may be recognized: intensive and extensive. Intensive drainage, aimed at increasing the productivity of the site, involves an engineered system of uniformly spaced ditches. The result is a high density of ditches intended to achieve an overall lowering of the water table for a site. With this approach, fertilizers may be used to address nutrient deficiencies or imbalances. Extensive drainage is a lower cost approach which involves more limited ditching to address particular problems. This may involve ditching in localized wet spots prior to harvesting and draining areas which have watered up following harvesting (Hånell 1991, Trettin *et al.* 1991, Jeglum 1993).

The use of wetland drainage for forestry is limited by economics. Installing and maintaining ditches and applying fertilizer are expenses which must be justified by anticipated returns from increased tree growth and sale of forest products. These factors will probably continue to limit the amount of drainage work in Canadian forests. Without subsidization, intensive drainage is unlikely to become widespread; on the other hand, extensive drainage is more likely to be applied to reduce local watering up in cutting operations (Jeglum 1993).

Potential Impacts of Forestry Operations on Wetlands

Two broad categories of forestry activity may affect wetlands: operations on wetland sites and upland operations near wetland areas. Forest access routes—roads and skid trails—can have the most extensive impacts in both upland and wetland forestry. Draining wetlands can have a range of effects depending on the extent and intensity of the drainage works.

Operations on Wetland Sites

Operating on wetland sites can be of particular concern because of the greater potential for site damage compared with many upland sites and because of the ecological and social values of wetlands described earlier.

Harvesting can be a damaging activity on peatland due to the sensitivity of these sites to damage by machinery and the resulting inhibition of regeneration. Primary impacts of harvesting occur only on wetlands with merchantable trees, mainly treed swamps. For the most part, harvesting does not take place on shallow waters, marshes, thicket swamps, fens and bogs. These latter wetlands can be subject to secondary impacts caused by forest roads, erosion or changes in hydrology.

The major problems in harvesting are disruption of drainage and soil mixing. Rutting and ponding of water occurs as skidders break through the surface and churn up the underlying peat. Seedling survival may be limited due to frost heaving and erosion, and competition from sedges, grasses, cattails and alder may be severe (Jeglum *et al.* 1983, Groot 1987).

The first kind of harvesting on Canadian wetland forest sites was "horse logging", normally done in winter. This system resulted in minimal damage to the site and normally left sufficient advance growth to establish second growth forests. Mechanization of forestry following World War II brought the use of rubber-tired skidders, increasingly large clearcuts and year-round operations. This cut and skid logging method tended to destroy much of the advance growth, and summer operations led to considerable disturbance of the ground surface (Jeglum 1991). In recent years, industry and forestry agencies have worked to develop new silvicultural procedures to reduce site damage and ensure regeneration. Studies of wide-tired skidders by the Forest Engineering Research Institute in Quebec are noteworthy (Mellgren and Heidersdorf 1984). Also see a following section entitled "Site-Specific Forestry".

An Ontario Clay Belt study (Groot 1987) of harvesting in black spruce peatlands found that the degree of site disturbance was strongly related to site characteristics and the type of harvesting. The study considered three harvesting systems on two black spruce site types (black spruce/Labrador tea (*Ledum*) and black spruce/green alder (*Alnus*/herb-poor) according to the Clay Belt Forest Ecosystem Classification (FEC) system (Jones *et al.* 1983). For more information about the FEC, see a following section entitled "Site-Specific Forestry". The three harvesting systems were:

- felling by feller-buncher and full-tree forwarding by narrow-tired skidder in winter;
- feller-buncher and full-tree forwarding by wide-tired skidder in summer; and
- conventional summer harvesting (felling manually by chain saw and tree-length skidding by narrow-tired skidder in summer).

The *Ledum* site type is poorer in nutrients and has a better developed fibric peat and root mat that is not broken through by machines as readily as the *Alnus* herb-poor type. The *Alnus* herb-poor site type suffered considerably greater damage from summer conventional harvesting than the Ledum type. The amount of rutting on both site types appeared greatest for conventional summer harvesting. To reduce site damage, it was recommended that any area with a significant proportion of peatland should be scheduled for winter harvesting. The study did not consider the effects of disturbance at roadsides and landings which may involve 10-15% of the cutover area. An overall evaluation and planning for wetland forestry operations should consider these factors.

When harvesting takes place within the basin form of swamp or treed fen, they often can experience a rise in the local water table or "watering up", since the rate of evapotranspiration on the previously treed site, and the interception of precipitation, are reduced. Hence the water table rises quickly and remains so for a few years until vegetation is reestablished and acts to lower the water. Often these basins are damaged during harvesting and develop into cattail/grass/sedge conditions which are very difficult to regenerate (Jeglum 1993).

Heavy site preparation on wet sites in the summer should be avoided. It can damage potential seed beds, create conditions for development of severe competition from dense grasses and sedges, and cause excessive erosion and siltation (Jeglum 1993).

Landings located within wetlands or interfering with wetland drainage can impair water quality and degrade habitat (Maryland Department of Natural Resources 1992).

Upland Operations near Wetlands

Potential problems for upland forestry operations include water quality effects related to erosion and runoff from logging conducted near wetlands. Another concern is site damage to wetlands as a result of such careless forestry practices as using marshes, fens or bogs for landing sites and logging equipment straying into nearby wetlands. Marshes, fens and bogs are flat open areas which can make convenient spots for landings in winter. However, this practice can damage vegetation and can deposit debris which enters the wetland with the spring thaw.

In gaining access to upland timber, skidders or other equipment may cross a wetland, sometimes repeatedly, causing rutting and damage to vegetation.

Draining Treed Wetlands for Forestry

A number of significant changes can be expected from draining peatland forests. These include an increase in the rooting zone, due to the lowered water table, and an increased rate of decomposition of the surface peat with a release of nutrients for the forest cover. The resulting increases in tree growth affect the lower vegetation and its growing environment. Plant communities typical of wet environments would change to those more characteristic of drier sites (Heikurainen and Pakarinen 1982).

Forestry Canada and the Ontario Ministry of Natural Resources are currently involved in an experimental drainage project in the Clay Belt region near Cochrane, Ontario. The Wally Creek Drainage Project, begun in 1984, applied ditching techniques developed for forestry in Finland to 375 ha of lowland black spruce forest. It is intended as a pilot project to develop operational drainage prescriptions and to evaluate the feasibility of broader scale drainage in Canadian peatland forestry. Studies associated with the project address both tree and seedling growth in response to drainage, costs of treatments and environmental effects (Rosen 1986, Jeglum 1991b).

The following is a summary of the main impacts that drainage has on forested peatlands:

Significant growth increases in young black spruce were demonstrated in an experimental drainage project by the Alberta Forest Service in a black spruce swamp, including diameter growth 2.3 and volume growth 5.0 times greater than trees on undrained control sites (Hillman 1991). A Quebec study of a tamarack swamp five years after drainage found increases in the diameter of saplings of up to 85% versus 15% on undrained control plots. Height increased up to 64% versus 10% for controls (Trottier 1991a). These and other studies in Finland and the United States have demonstrated varying degrees of increase in tree growth due to drainage, with the growth response being related to site characteristics and distance of the trees from the drainage ditch.

Nutrient depletion could be among the effects of drainage, by stimulating tree growth, or by lowering the water table and thereby increasing the effect of precipitation flushing out nutrients. However, Finnish researchers who studied nutrient stores in peat on a forest site 55 years after drainage found no drastic changes in nutrient status (Laiho and Laine 1991).

Disruption of the natural runoff regime can be one of the more serious concerns in forest drainage (Vompersky *et al.* 1992). A study for the Wally Creek Drainage Project in Ontario found increases in snowmelt and storm flows in one basin and decreases in another. Both basins showed increases in summer low flows. The occurrence of increases or decreases was linked to the nature of the drainage basins and the ditch systems. The study concluded that drainage does not necessarily adversely affect streamflow, especially if the area drained was only a portion of the catchment area (Berry 1991a).

Water quality effects of forest wetland drainage depend on the wetland type, the parent material of the underlying soil, plant species and climate. In Finland, discharge waters from peatland forest drainage projects have been found to have large quantities of organic matter, suspended solids and leached nutrients. The increase in suspended solids may be the most serious of these effects and the problem is most evident shortly after ditching (Joensuu 1991). Wally Creek researchers found that drainage increased pH and increased concentrations of ions and alkalinity in adjacent streams. They also found that water quality 5 km downstream of the outlet ditch was not significantly degraded.

However, only 7% of the subject watershed had been drained and they stated that water quality impacts could have been greater with more extensive drainage works (Berry 1991b).

Adverse effects on certain wetland plant communities could result from forestry practices that increase the availability of nutrients. University of Ottawa researchers studying a variety of wetland types in eastern Canada found that infertile (low standing crop) wetlands had higher species richness and many more rare species than did fertile wetlands (Moore *et al.* 1989, Wisheu *et al.* 1990). Depending on the initial conditions in an infertile wetland, eutrophication could either increase or decrease species richness. However, since rare plants were found to favour the low biomass sites, eutrophication could be cause for concern from a conservation standpoint.

The *ecological effects* of peatland drainage have been addressed by Finnish researchers for several decades. Predictions about the rate or direction of forest succession have proved inaccurate in some cases (Reinikainen 1991). This

Photo: G. Sheehy

A forest road restricting drainage, causing flooding on the upstream side.

indicates the need for better knowledge of the ecological effects of drainage to ensure the desired results and to avoid unforeseen environmental impacts.

Forest Access

Roads that cross wetlands frequently block drainage. The common result is flooding on the upstream side of the road with subsequent killing of woody vegetation and partial drying of the downstream area. The upstream area may therefore convert to open marsh or fen communities or to open water (Jeglum 1989). Disturbing a stream channel can affect both the direction and rate of flow, altering drainage patterns, increasing channel scour, erosion and flooding (Baker 1991).

Roads in upland areas can cause soil erosion and sedimentation of adjacent surface waters. Some of the causes include: changing or disturbing the natural flow of drainage channels, roads with steep gradients resulting in erosion, and drainage systems inadequate to divert water from road surfaces (Corner Brook Pulp and Paper Limited 1991).

Roads through wetlands tend to have a lower risk of erosion and sedimentation than those on many upland sites. However, the potential for other hydrological problems such as diversion or blocking of drainage is greater than for uplands (Baker 1991). Roads on wet sites may require extensive preparation of the road bed, with a variety of measures to handle drainage. The extent of these measures and the potential impact on wetland sites may be reduced considerably by accessing these sites in the winter using ice or winter roads which do not require a built-up grade.

Photo: G. Sheehy

Low ground pressure logging equipment: a wide-tired skidder.

Photo: Forest Engineering Research Institute of Canada

Shear blading, a technique to prepare a site for planting or seeding, is done during the winter to minimize site disturbance.

Measures to Remedy or Reduce Impacts of Forestry Operations

Forestry agencies and forest product companies in a number of jurisdictions have developed measures to deal with the wetland concerns described above. These include new silvicultural measures to reduce disturbance of wet sites, road construction techniques to maintain drainag$ and control erosion, and forest management approaches which integrate wildlife conservation measures with timber supply. Research and development efforts in a number of areas are improving the tools for wetland-compatible forestry operations. Several examples are presented here.

Site-Specific Forestry – the Ontario Experience

Recognition of the site damage and associated problems with regeneration, which can result from conventional logging techniques on peatland, has been an important incentive to develop the new "site-specific phase" (Rosen 1986) of peatland forestry in Ontario's Clay Belt. This latest stage in evolution from the horse logging and wheeled skidder phases has a number of important aspects:

- the Forest Management Agreement (FMA) system transfers responsibility for regeneration from the Crown to companies;
- development of a detailed site classification, the Forest Ecosystem Classification (Jones *et al.* 1983); and
- innovations in equipment and silvicultural practices to improve regeneration success on peatland cutovers (Rosen 1986).

The FMA system was initiated in 1980 when Abitibi-Price in Iroquois Falls, Ontario became the Ontario Government's first FMA partner. Under FMAs, companies are responsible for the silvicultural work in their licence areas. This is intended to ensure prompt and effective regeneration of cutovers. The penalty for missing regeneration targets is a corresponding reduction in allowable cut (Haavisto *et al.* 1988). Companies are reimbursed for a portion of their regeneration costs based on agreed silvicultural systems termed "harvesting and regeneration options". These systems are developed for particular classes of sites according to the Forest Ecosystem Classification (FEC) (Ecological Services for Planning Ltd. 1987). The FEC identifies Clay Belt site types which have predictable responses to silvicultural treatments (Haavisto *et al.* 1988). This has resulted in development of criteria for harvesting and silvicultural prescriptions that aid forest managers in making informed decisions, resulting in reduced site impacts. Forestry field personnel in the Clay Belt are becoming very adept at recognizing and distinguishing FEC site classes (Rosen 1989).

A recent development in logging on Ontario's peatlands has been the use of wide tires or wide tracks to reduce the ground pressure of logging equipment and the resultant site damage from rutting. This has been accompanied by increasing use of larger equipment (skidders and forwarders) which can move more trees at a time, thus reducing the number of passes over the ground.

Together these measures can reduce the extent and severity of site damage, protect the advance growth and improve prospects for regeneration. These changes in equipment have been combined with other measures to develop a concept of "careful logging" (Jeglum 1991a) or "careful logging around advance growth" (Jeglum *et al.* 1983, Gingras *et al.* 1991). These measures include:

- following defined skid trails with logging equipment (feller-bunchers or feller-delimbers) to preserve advance growth between the trails;
- using longer booms on feller-delimbers to widen the space between trails; and
- using skidding and forwarding machines and methods to minimize damage to advance growth (Jeglum 1991a).

Site preparation can enhance black spruce regeneration from seed (although it would reduce the amount of advance

Photo: G. Sheehy

A logged site showing results of careful logging to protect advance growth. Young trees were present on the site at the time of logging.

growth which may be present). The low bearing strength of the peat surface is a problem for equipment in the frost-free periods. This has led to the development of "shear-blading", a site preparation technique which involves bulldozers with blades sharpened at the bottom edge. Shear blading is used when the intent is to plant or direct seed. It is done in winter to avoid rutting and breaking through the top root mat. Competing vegetation is thus removed while the site is relatively undisturbed, leaving a good seedbed for spruce (Ecological Services for Planning Ltd. 1987, Pelletier 1991).

Photo: G. Sheehy

A cross-drain culvert installed to direct drainage under a road bed. Note the berm constructed behind the culvert to control drainage along the right-of-way.

Seasonal restrictions for operations on wetland sites can reduce potential impacts. Harvesting wet sites in winter can reduce rutting and prevent the accumulation of water through pooling. Winter roads often reduce the need for stream crossing structures and eliminate the requirement for built-up grades. This will reduce the risk of blocking water flow in wetlands and lessen the potential for erosion at stream crossings. Similar approaches to site-specific forestry are being developed and implemented across the country.

Consulting the Experts

A number of companies have responded to increasing concerns about non-timber values of forest land by hiring biologists to work with woodlands staff. The biologist may be a permanent staff member or a consultant, usually acting as an advisor to planning and field staff on ways to incorporate wildlife and non-timber values in the forest management plans and operations. This may include recommending cutting measures to maintain or enhance habitat or working with road construction personnel to develop mitigation and site rehabilitation techniques to control erosion and sedimentation at stream crossings. The company biologist, working with planning, road construction and logging personnel, helps to identify problems and devise solutions (Smith 1992). This approach can be quite effective to develop site-specific, cost-effective measures to remedy existing problems, prevent problems from occurring and to remedy unforeseen impacts. Among the measures which have been applied are:

- installing cross-drain culverts to direct runoff under the roadway and into the bush;
- constructing berms to direct water into cross-drains;
- installing sediment ponds to treat runoff from bare soil areas (sediment ponds would be placed in a ditch system to slow the water and cause suspended solids to settle out);
- stabilizing eroding soils with a cover of crushed stone; and
- using selected seed mixtures to stabilize erodible soils.

Planning for Wildlife Habitat

In several provinces, forest products companies have joined with wildlife agencies and non-government conservation organizations to integrate wildlife habitat needs in timber management plans. Examples of these innovative projects include:

- In New Brunswick, the **Forest Land Habitat Management Program** involves developing and testing relationships between wildlife species and forest habitats. A major objective is to define explicit objectives to achieve the amount and distribution of forest habitat classes required to meet desired wildlife population levels for each of ten timber licences (Wildlife Habitat Canada 1992).
- In Manitoba the **Forestry/Wildlife Management Project** is a cooperative venture with the Manitoba Department of Natural Resources, Abitibi-Price Inc., REPAP Manitoba, Wildlife Habitat Canada and Forestry Canada through the Canada/Manitoba Partnership Agreement in Forestry and the Manitoba Habitat Heritage Corporation. It is developing a process to assist resource managers in estimating wildlife habitat values in the forest. Through selection of key indicator wildlife species, models will be developed and incorporated into a geographic information system to predict the impact of forest management practices on the supply and quality of habitat for resident wildlife. This will allow resource managers to evaluate forest management options and modify plans if necessary (Manitoba Department of Natural Resources *et al.* 1992).

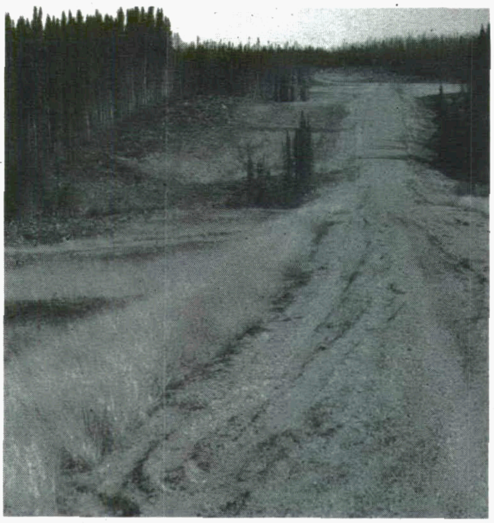

Photo: G. Sheehy

This road, constructed down a long slope on erodible soil, has been stabilized using crushed stone and seeding with grasses.

- In Saskatchewan, the **Integrated Forestry/Wildlife Program** involves Wildlife Habitat Canada, Weyerhaeuser Canada Ltd., the Saskatchewan Wildlife Federation, federal and provincial agencies and other organizations. This is a five-year effort to identify key wildlife species and

Photo: G. Sheehy

A sediment pond maintains water quality for runoff from a road.

determine their populations, conduct a habitat inventory, develop a computerized habitat suitability analysis, and integrate habitat goals in forest harvesting plans (Wildlife Habitat Canada 1992).

- In the Alberta **Weldwood Hinton Timber-Wildlife Integrated Management Project,** Weldwood of Canada Ltd. is working with the Alberta Department of Forestry, Lands and Wildlife to develop a cooperative modelling approach to predict future supplies of timber and wildlife habitat. The project examines at the landscape level, the long-term effects of timber management proposals on wildlife habitat. It will be used to coordinate objectives and improve management systems on the Weldwood Forest Management Agreement at Hinton, Alberta (Bonar 1991).

- In Quebec, the **"Action Aménagement"** committee involves Domtar Inc., the ministère du Loisir, de la Chasse et de la Pêche, the ministère des Forêts and the Fondation de la faune du Québec. The committee was established in 1985 to develop a forest management strategy that could be applied to deer yards located on Domtar's properties and Crown lands. The resulting 70-year plan (revised every five years) describes objectives and techniques to be adopted for sustaining the potential of the forest and its wildlife for the predetermined areas (Dorval 1993).

Photo: NAWCC (Canada)

The Upper Humber River wetland complex is Newfoundland's most important waterfowl production area.

Photo: Stora Forest Industries Ltd.

Portable steel bridges are one method of stream protection in forwarder operations.

- In British Columbia, Fletcher Challenge Canada developed the **Coastal Blacktailed Deer Winter Capability Mapping Project** in cooperation with the B.C. Ministry of Environment, Lands and Parks, and the B.C. Ministry of Forests. The project integrates biogeoclimatic data, topographic/physical parameters (slope and aspect), and snow zonation in a mapping system to facilitate the development of a comprehensive land use strategy. The use of a geographic information system allows the overlapping of the mapped data bases, the rating of integrated parameters, and the production of an interpretive map illustrating the deer winter habitat capability of the land base. The mapping system will be used to guide harvesting deferrals of old growth timber areas with high potential for deer winter habitat (Lindsay 1993).

These integrated planning approaches could have considerable merit for accommodating wetlands and associated wildlife in land management on a regional scale.

Cooperation for Wetland Conservation

Companies can do a great deal for wetlands by joining others in partnership for conservation projects.

Corner Brook Pulp and Paper is joining with the Newfoundland and Labrador Department of Environment and Lands and Ducks Unlimited Canada to protect and enhance habitat in the **Upper Humber River** wetland complex. These wetlands, which fall within the company's operating limits, are the province's most important waterfowl production area. This undertaking is part of the Eastern Habitat Joint Venture of the *North American Waterfowl Management Plan.* The project partners are implementing a land stewardship agreement which enables the provincial government to establish a wildlife reserve in the area and the company to carry on compatible forestry operations (Soper 1990).

In Nova Scotia's **Saint Mary's River Forestry/Wildlife Project,** Stora Forest Industries Ltd. and Scott Maritimes Ltd. are working with federal and provincial resource agencies, Wildlife Habitat Canada and other conservation groups to integrate wildlife concerns in intensive forest management systems. This includes developing techniques to maintain and enhance riparian habitat (Wildlife Habitat Canada 1992). Among the products of this project is a video on stream protection in forwarder operations (Camozzi 1991). The video describes such innovative measures as portable steel bridges and log bridges developed by Stora Forest Industries. One of these reusable bridges, suitable for streams up to three metres wide, can be delivered and installed in minutes by the grapple forwarder which then uses the bridge to cross the stream.

Cooperative wetland conservation can be carried out at any scale. In one small but noteworthy project, Corner Brook Pulp and Paper used innovative road building techniques to cross a marshy creek while enhancing habitat for waterfowl. Ducks Unlimited Canada (DUC) was involved in the project along with Fisheries and Oceans Canada. DUC helped design the stream crossing structure, and Fisheries and Oceans identified the need for fish habitat protection measures. The company provided the staff and equipment to build the crossing structure which consists of an earth fill dam incorporating a concrete fish passage structure. Company staff installed waterfowl nesting boxes along the margins of the enhanced wetland.

Protecting Sensitive Aquatic Features

A variety of measures may be used to minimize the impact of forestry operations on surface waters and aquatic habitats. One such situation which has occurred in a number of jurisdictions in Canada is the protection of water quality for municipal water supply watersheds. Corner Brook, Newfoundland is one such case, where the municipal water supply comes from Corner Brook Pulp and Paper's operating limits. To enable forestry operations to proceed within the watershed, the company worked with a number of government agencies to develop the *Corner Brook Watershed Harvesting Guidelines* (Corner Brook Pulp and Paper Limited 1991). This manual describes a broad range of operational measures to maintain water quality and quantity. While not strictly concerned with wetlands, the general approach and a number of the specific guidelines are relevant to wetland conservation.

The manual is intended for company field staff and loggers. In a concise format, it begins by describing the relevant regulations and required permits for operating within the watershed. It then describes specific measures for road construction, stream crossings, buffer zones, harvesting on steep slopes, fuel handling and storage, and response procedures for accidental spills.

Photo: G. Sheehy

Special construction measures for a road crossing a marshy creek. The road bed is an earth fill dam which raises the water level to enhance the wetland for waterfowl habitat. A fish pass structure is in the middle of the photo.

Best Management Practices — the U.S. Experience

The *Clean Water Act* of the United States establishes national water quality goals and identifies various land management practices as potential causes of erosion and sediment pollution. For forestry, the identified practices of concern are road construction, harvesting and site preparation. To implement the *Act*, individual states develop what are termed "Best Management Practices" (BMPs). These are management and silvicultural techniques to prevent erosion at the source (Baker 1991). Some states have developed quite specific and detailed BMP guidelines and procedures to apply to wetlands, stream crossings and shoreline areas. These are outlined in a following section entitled "Other Handbooks and Manuals".

Minnesota, which contains boreal forests and wetlands similar to some areas of central Canada, has developed an innovative BMP approach. This involves a manual entitled *Water Quality in Forest Management* (U.S. Forest Service *et al.* - undated) and an independent audit procedure to evaluate companies' compliance with BMP requirements (Rossman and Phillips 1991). This small, "hip pocket" manual describes general water quality measures such as filter strips along streams and fuel and equipment handling procedures. It also contains specific guidelines for:

- roads — design, construction and maintenance;
- harvesting — planning, design, operations and follow-up;
- site preparation — planning, recommended prescriptions and alternatives;
- pesticide use — pesticide selection, integrated pest management and handling procedures; and
- prescribed burning — planning, prescriptions and after-fire maintenance.

The audit procedure involves field visits by an evaluation team which includes a wide range of interests and expertise drawn from federal, state and county agencies, academia and conservation organizations. Audit forms are based on the BMPs described in the *Water Quality* manual. For each BMP applicable to the forestry operation being evaluated, the audit team assigns a rating from 1 ("gross neglect") to 5 ("operation exceeds requirement").

Mississippi's Best Management Practices for Wetlands (Baker 1991) was developed for forestry operations in the state's extensive bottomland areas. Maryland's *Guide to Forest Harvest Operations and Best Management Practices* (Maryland Department of Natural Resources) is a detailed manual which contains environmental protection measures at varying levels of restriction of forestry activities.

The National Council of the Paper Industry for Air and Stream Improvement (NCASI) is a research and advisory body of the United States forest industry. In 1989 it established a Forested Wetlands Environmental Research Program to determine how companies can "manage forest wetlands for timber production while providing for other important wetland functions such as water quality maintenance, streamflow discharge regulation and wildlife protection" (Ice and Lucier 1990). The program has three major goals:

- identify and characterize important forest wetland types of the United States;
- develop technically sound methods for measuring the functions and values of important forest wetland types; and
- determine effects of commercial timber management on the short- and long-term functions and values of forest wetlands to facilitate identification of economically feasible Best Management Practices.

As an initial stage in the program, the NCASI organized a symposium to address environmental concerns, assessment techniques and management options related to forest wetlands. Published in a technical bulletin (NCASI 1990), the papers from the symposium address a number of issues relevant to forestry-wetland interactions in Canada.

Environmental Protection in Forest Drainage

Finnish forest drainage projects incorporate a variety of measures to prevent suspended solids from reaching lakes or streams. These include:

- minimizing the velocity of ditch water;
- leaving buffer/filter strips of undisturbed vegetation for overland flow of water between ditch outlets and receiving streams;
- using temporary dams during ditch construction; and
- digging sedimentation pits and ponds at strategic locations within the drainage system (Joensuu 1991).

The Wally Creek Drainage Project includes several of these measures which are described in a *Forest Drainage Manual* developed by the Ontario Ministry of Natural Resources (Rosen 1989). As well, the Quebec ministère du l'Énergie et des Ressources has developed a manual entitled *Guide sur le drainage sylvicole* to assist in planning drainage to minimize impacts on the site.

A study in Michigan of wildlife, forest harvesting and drainage (Trettin *et al.* 1991) emphasized that habitat niches are strongly influenced by silvicultural prescriptions. The researchers in this study concluded that drainage projects offer opportunities for sustaining or enhancing wetland wildlife values. Designing cuts to increase edge habitat and retaining snags are important considerations. Ditches also provide aquatic habitat. Maintaining or enhancing species' richness requires that specific habitat objectives be included as part of the silvicultural prescription.

Other Handbooks and Manuals

In addition to the procedural manuals described earlier, there are a number of publications, some quite detailed, which describe environmental protection measures relevant to forest operations in or near wetlands. Some were developed specifically for wetland forestry (South Carolina Forestry Commission - undated, North Carolina Department of Environment, Health and Natural Resources 1990, Georgia Forestry Association 1990). Others address environmental concerns for harvesting or road building on a variety of sites (Racey *et al.* 1989, McCubbin *et al.* 1990, Quebec ministère de l'Énergie et des Ressources 1990, Newfoundland Department of Forestry and Agriculture and Newfoundland Forest Service 1992). Still others focus on habitat needs of wetland wildlife species (James 1984 and 1985, Ontario Ministry of Natural Resources 1988a and 1988b). Most, if not all, resource agencies have developed such manuals or guidelines.

Most provinces in Canada have developed guidelines for forestry operations in riparian zones and fish and wildlife habitat protection. Ontario's Ministry of Natural Resources has a comprehensive Canadian program applicable to wetland/forestry interactions. The Ministry has produced a video, *Cutting Near the Edge,* which briefly describes concerns and appropriate timber management practices for wetlands and riparian zones. The video introduces three manuals intended for resource managers: *The Code of Practice for Timber Management Operations in Riparian Areas* (Ontario Ministry of Natural Resources 1991); *Timber Management Guidelines for the Protection of Fish Habitat* (Ontario Ministry of Natural Resources 1988); and *Environmental Guidelines for Access Roads and Water Crossings* (Ontario Ministry of Natural Resources 1990).

Conclusion

Wetland conservation measures need not unduly restrict forestry operations, nor are they likely to add significantly to industry's costs. Many creative solutions to conservation problems are already in use in Canada and elsewhere. Broader application of established techniques will serve to maintain these vital habitats.

The results of this study suggest a number of recommendations for wetland-compatible forestry:

(1) *Good road construction*, with adequate provision for drainage, and revegetation of roadsides susceptible to erosion, should be standard practice. The environmental impact of a stream crossing on a valuable aquatic habitat is not lessened because it is located on a lower standard road and not a primary road (Ontario Ministry of Natural Resources 1990). Similarly, the overall impact of a road is determined by the crossing measures used for all drainageways: environmental protection measures are required for small creeks and brooks as well as major streams.

(2) *Site classification systems* for wetlands are particularly important. Sometimes these are only partly covered by existing forest classification systems. These systems need to be province-wide and need to be expanded into the non-commercial forested wetlands and the open wetlands. Federal and provincial agencies should develop these systems with input from forest operators and biologists as well as experts in forest-site relationships. Classification systems must be supported by inventories of wetland flora and fauna. This will assist development of site-specific silvicultural treatments and appropriate wetland protection measures.

(3) *Harvesting operations should be carefully planned*, using good site-type information. Knowledge of the distribution of site types allows planners to schedule logging operations accordingly, thereby reducing site damage.

(4) *Winter logging* is a proven method which should be used where necessary to minimize site damage. Operating on frozen surfaces or with snow cover avoids the problems of rutting and compaction and also reduces damage to advance growth (Jeglum *et al.* 1983, Groot 1987, Groot 1992). Winter roads reduce the potential for site disturbance, erosion at stream crossings and disruption of drainage. The move by the forest industry to low ground pressure logging equipment allows greater access to wetter areas in frost-free periods. This may lead to greater site impacts (Groot 1992). Where summer peatland operations are unavoidable, site-specific information should be used to select the least fragile sites. Low ground pressure equipment should also be used when summer operations are necessary.

(5) *Industry planning and operations staff should be informed* of the values of wetlands so that they may consider these values in cutblock design, block layout and harvest supervision. This educational effort should involve government agencies and non-government groups as well as industry.

(6) *Equipment operators should have training* to recognize sensitive sites and avoid damaging practices (Groot 1987). A good operator using any kind of equipment may be better than a careless one using the best equipment (Groot 1992).

(7) *The forest industry should use special expertise* to ensure that wetland values are incorporated effectively in planning and executing forestry operations. A number of companies have biologists on staff or under contract. These specialists should exchange information and cooperate on research.

(8) *Cooperative habitat conservation efforts* such as the Upper Humber Eastern Habitat Joint Venture Project and the Saint Mary's River Forestry/Wildlife Project should be expanded. These offer excellent opportunities for companies, agencies and conservation groups to pool resources. The North American Waterfowl Management Plan provides an umbrella for many new and innovative projects to be developed. The plan has an ambitious objective: to restore waterfowl populations continent-wide. Sensitive management of forest lands is integral to its success, and the forest industry can make an important contribution to this end.

(9) *Research and development* in the areas of low-ground-pressure equipment and careful logging such as that being done by the Forest Engineering Research Council (Mellgren and Heidersdorf 1984, Gingras *et al.* 1991) must continue.

(10) *Forest management codes of practice and guidelines* should include wetland conservation considerations adapted for specific regions in Canada.

(11) *The design of shoreline buffers and filter strips* requires careful thought. These should consider the characteristics of individual sites rather than following strict guidelines applying to broad geographic areas. The survival of buffer strips can be an important issue. In some cases trees may be blown down within a few years, offering little benefit for stream stability or water quality. On-site judgements and variations in buffer strip dimensions based on site conditions may be better than fixed widths. The requirements of terrestrial and aquatic resources should determine the design of the buffer (Garland 1987). Landscape level habitat analyses and integrated timber/wildlife management such as New Brunswick's Forest Land Habitat Management Program and the Manitoba Forestry/Wildlife Management Project will achieve more for wetlands and wildlife than will uniform leave strips along shorelines.

(12) *Further environmental assessment of forest drainage proposals,* should be used as a tool for identifying and alleviating the impacts of forest drainage, with site-specific mitigation measures to be implemented as necessary (Rosen 1989, Jeglum 1991b). Extensive drainage measures are likely to have less significant impacts than intensive systems. Limiting the total area drained within a given watershed could also reduce the potential water quality impacts (Berry 1991b). Forest managers should take special care in fertilizing drained sites. Eutrophication of wetlands should be avoided where this will adversely affect existing plant communities (Wisheu *et al.* 1990).

Wetland conservation measures need not unduly restrict forestry operations, nor are they likely to add significantly to industry's costs. Many creative solutions to conservation problems are already in use in Canada and elsewhere. Broader application of established techniques will serve to maintain these vital habitats.

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