The Alberta GPI Accounts: Wetlands and Peatlands

Report # 23

by

Sara Wilson
Mary Griffiths
Mark Anielski

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Pembina Institute
for Appropriate Development

About the Pembina Institute

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For more information on the Pembina Institute's work, please visit our website at **www.pembina.org**, or contact:

The Pembina Institute
Box 7558
Drayton Valley, AB   T7A 1S7
tel: 780-542-6272   fax: 780-542-6464
e-mail: info@pembina.org

About this Report

This is one of 28 reports that provide the background for the Genuine Progress Indicators (GPI) System of Sustainable Well-being Accounts. It explains how we derived the wetlands and peatlands sustainability indices that were earlier published in *"Sustainability Trends 2000: The Genuine Progress Statement for Alberta, 1961 to 1999."* The research for this report was completed near the end of 2000. The appendices provide further background and explanation of our methodology; additional details can be obtained by contacting the authors. Appendix A includes a list of all GPI background reports.

This report examines the extent of peatlands and wetlands in Alberta. It attempts to answer the following questions:

1. What is the current state of Alberta's peatlands?
2. How much is being mined for horticultural purposes?
3. How much carbon do peatlands sequester on an annual basis?
4. What is the current status of wetlands in Alberta?
5. What have been the environmental and economic impacts of wetland drainage?
6. What are the benefits of these ecological services and what are the full costs of degrading Alberta's wetlands?

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About the Authors

Sara Wilson joined the Pembina Institute in August 2000, as a member of the Green Economics Program. She works on establishing measurements of ecological well-being and community sustainability reflected in genuine progress indicators using time series analysis and valuation methods. Sara aims to promote better physical and economic accounts that will reflect our natural capital, quantitative and qualitative degradation, and the ecological and social costs of losses in ecological integrity. Before joining the Green Economics team, Sara completed the water account and forest account for the Nova Scotia GPI. In addition, she has three years' experience as a forest ecology researcher and three years' experience in environmental education. Sara holds the following degrees: MSc.F. (Mixed Boreal Forest Disturbance Ecology), University of Toronto, and B.A. Hon. (International Development Studies and Environmental Geography), University of Toronto.

Mary Griffiths joined the Pembina Institute as an Environmental Policy Analyst in May 2000. She brings strong research and policy analysis skills as well as an extensive background and in-depth understanding of a wide range of environmental issues. Mary works with the Energy Watch team on environmental and energy advocacy issues and with the Institute's Green Economics Program on genuine progress indicators for Alberta. She has long been an advocate for the protection of the environment, both in her previous employment and in her volunteer activities. Mary holds a Ph.D. (Medical Geography), University of Exeter, UK and a B.A. (Geography), University of Exeter, UK.

Mark Anielski is Director of the Green Economics team, and has considerable experience in public policy analysis including natural resource, energy, royalty and fiscal policy issues in both the public (Alberta Government) and private (GPC – Government Policy Consultants) sector. He also serves as Senior Fellow to the U.S. economic policy think-tank Redefining Progress in Oakland, California and authored the 1999 U.S. GPI report with journalist Jonathan Rowe. He currently advises the National Round Table on Economy and the Environment's Sustainable Development Indicator Steering Committee on the development of indicators for measuring sustainability in Canada. Mark teaches business and the environment in the University of Alberta's School of Business. His expertise is varied and broad including accounting for sustainable development, natural resource accounting, public policy analysis, business planning and performance measurement. Mark pioneered the development of natural capital accounts for Alberta's timber, oil, gas, coal and other natural capital as well as having experience in the development of performance measurement systems, land use planning and non-market resource valuation, royalty policy analysis (forestry, oil and gas), and analysis of subsidies for both government and private forestry, energy and financial service industries. He holds a Masters degree in forest economics, plus bachelor degrees in economics and forestry.

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We also thank Kim Sanderson for her editing assistance. Finally, the Pembina Institute appreciates the vision of Western Economic Diversification in supporting this project—the first of its kind for Alberta, if not internationally.

The contents of this report are the responsibility of the Pembina Institute and do not necessarily reflect the views and opinions of those who are acknowledged above or the opinions or positions of Western Economic Diversification who helped fund the research.

We have made every effort to ensure the accuracy of the information contained in this document at the time of writing. However, the authors advise that they cannot guarantee that the information provided is complete or accurate and that any person relying on this publication does so at their own risk. Given the broad scope of the project and time constraints, it has not been possible to submit the entire report for peer review. The material should thus be viewed as preliminary and we welcome suggestions for improvements that can be incorporated in any later edition of the work.

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1. Executive Summary

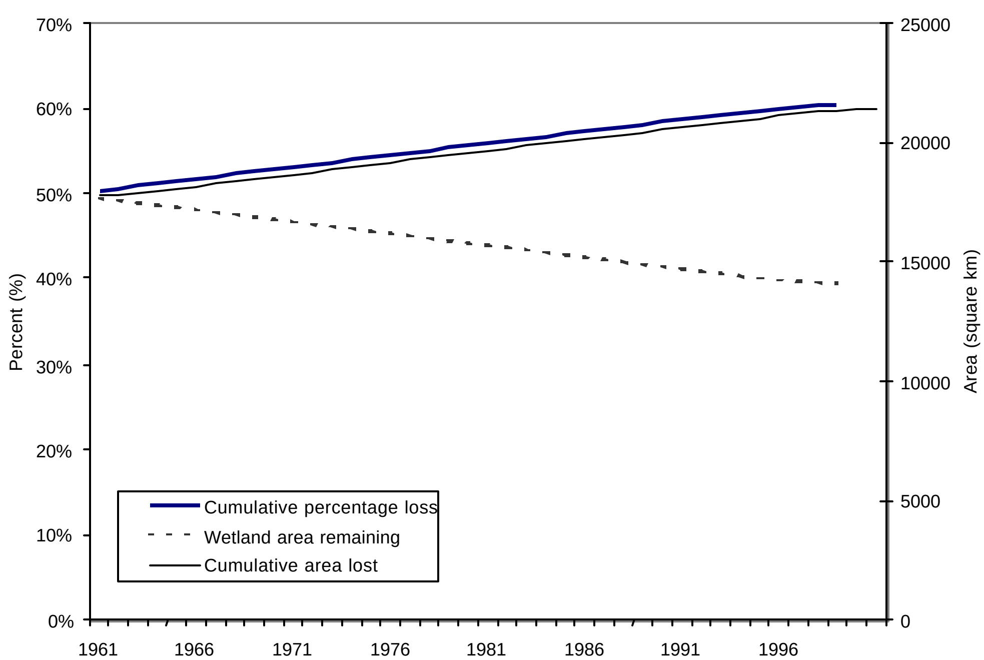
1.1 The State of Alberta's Wetlands

Wetlands provide many services including water purification and storage, flood control, shoreline stabilization, and recreation. Both peat and non-peat wetlands absorb water from spring snowmelt and summer storms, reducing flooding, erosion and sedimentation, and recharging the water table in times of drought. They are natural filters, cleansing the water that passes through them. Wetlands provide habitat for a wide variety of plants and wildlife, including rare and endangered species. It is estimated that about 50 percent of Alberta's original wetland area was gone by 1960, and about 60 percent had disappeared by 1996. Based on the 1996 inventory, the original extent of wetlands would have been about 35,500 sq km. Therefore, an estimated 17,750 square kilometres of Alberta's wetlands (50 percent of the estimated pre-settlement wetlands) had been lost by 1960, 21,300 square kilometres (60 percent) by 1996, and 21,500 square kilometres by 1999. The area remaining is about 14,000 square kilometres.

Noteworthy

- In 1996, the total area of wetlands was about 14,000 square kilometres; the grand total of peatlands and wetlands in Alberta, was approximately 117,400 square kilometres, or about 18% of the province.
- The cumulative loss of wetlands and the long periods of drought during the 1970s and early 1980s caused waterfowl populations to decline by 1/3 in the mid-80s.
- Alberta has lost non-peat wetlands due mostly to draining for agricultural land and land development.
- The estimated total area of wetlands and peatlands was about 91,444 square kilometres in 1996.
- A study of wetlands in a portion of the agricultural area of Alberta in the 1980s indicated that 66% of the remaining wetlands had been adversely affected by agriculture, while the degradation at the margins (which included haying, clearing, grazing and cultivating) was as high as 93%.
- Research in Saskatchewan found that in three of the six years studied, between 9% and 24% of the wetlands examined had pesticide levels that exceeded the guidelines for the protection of aquatic life.
- Not until 1990 did the Alberta government recognize the need to conserve wetlands.

Percentage of Wetland Area Lost and Percentage Remaining in Alberta, 1961 to 1999

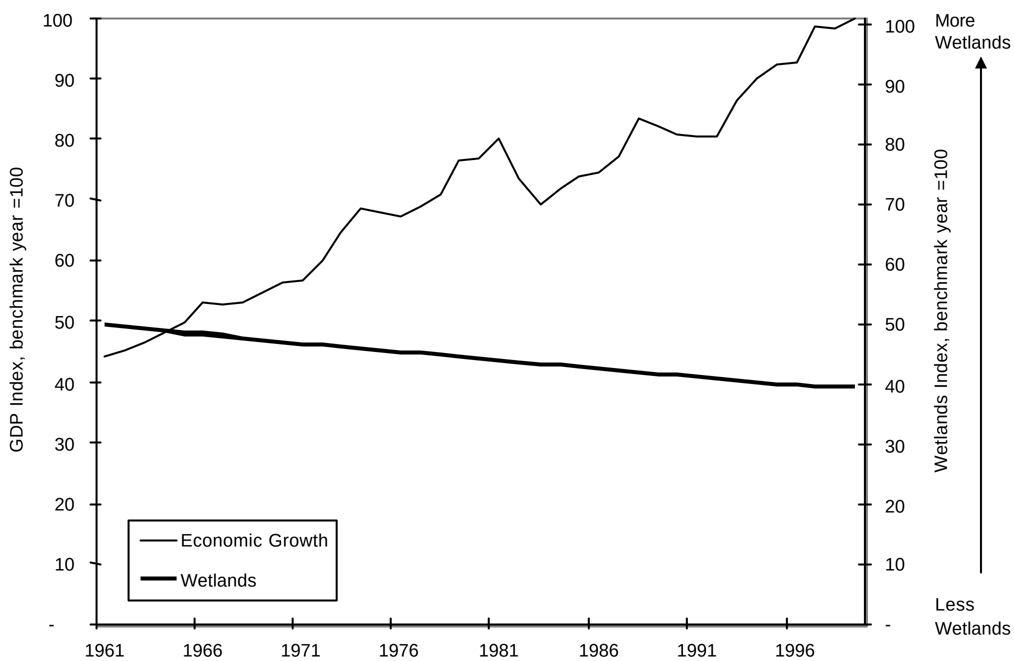


Source: Estimates based on 1996 Alberta State of the Environment Report

So What?

The figure below compares Alberta's wetlands as an index with provincial GDP as an index. The estimated original area, approximately 35,500 square kilometres, was set equal to 100 on the index for wetlands. The other end of the index represents zero square kilometres of wetlands. In 1961, the status of Alberta's wetlands was 49.7; by 1999, the index had dropped to 39.6.

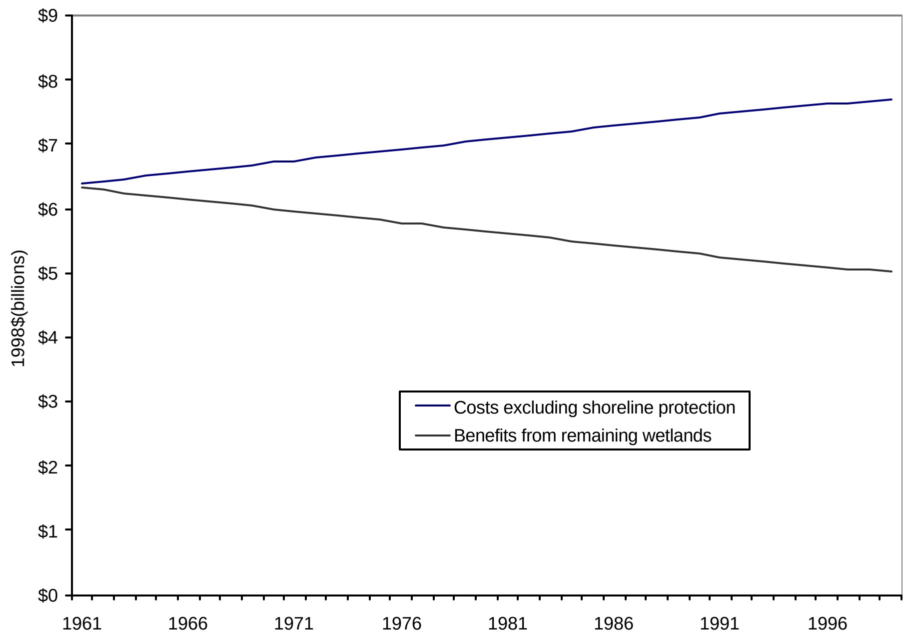
Alberta's Wetland Index: Where are we today?



Wetlands provide habitat for wildlife, migratory birds and fish; flood and stormwater control; water filtration; shoreline protection; groundwater replenishment; and aesthetic, recreational and educational values. When wetlands disappear, the loss of ecosystem function (e.g., wildlife habitat and water purification) implies that costs are incurred. In addition, the intrinsic values of wetlands are lost. The estimated dollar value used to calc ulate the annual cost of lost wetlands—$3,650 per hectare (1998$)—is based on the average annual value of the wetland services from several studies in Minnesota and South Dakota. The annual economic benefit of wetlands remaining has declined from $6.3-billion in 1961 to about $5.0-billion in 1999. The annual cost due to the estimated cumulative loss of 50 percent of Alberta's wetlands by 1960, was an estimated $6.4-billion (excluding shoreline protection services). By 1999, when the estimated cumulative loss of wetlands was 60.3 percent, the estimated annual cost was $7.7-billion. If we assume that 50 percent of the lost wetland area provided shoreline protection services, then the estimated annual cost was about $15.5-billion in 1961 and $18.6-billion in 1999. If the annual value per hectare estimated by Costanza et al. (1997) is used, then the costs range from $38.0-billion in 1961 to $45.7-billion in 1999.

The cost of the estimated loss in cumulative area of Alberta's wetlands was $7.7-billion (1998$) in 1999, equal to seven percent of Alberta's 1999 GDP. The annual value of remaining wetlands in 1999 was $5.0-billion to $30-billion. On a scale of 0 to 100, where 100 is best, the status of wetlands ranked 39.6 in 1999.

Cost of lost wetland services due to cumulative losses in wetland area and the economic benefits of wetland remaining in Alberta, 1961 to 1999 (1998$)



Source: Cost estimates based on values from Sip et al. 1998

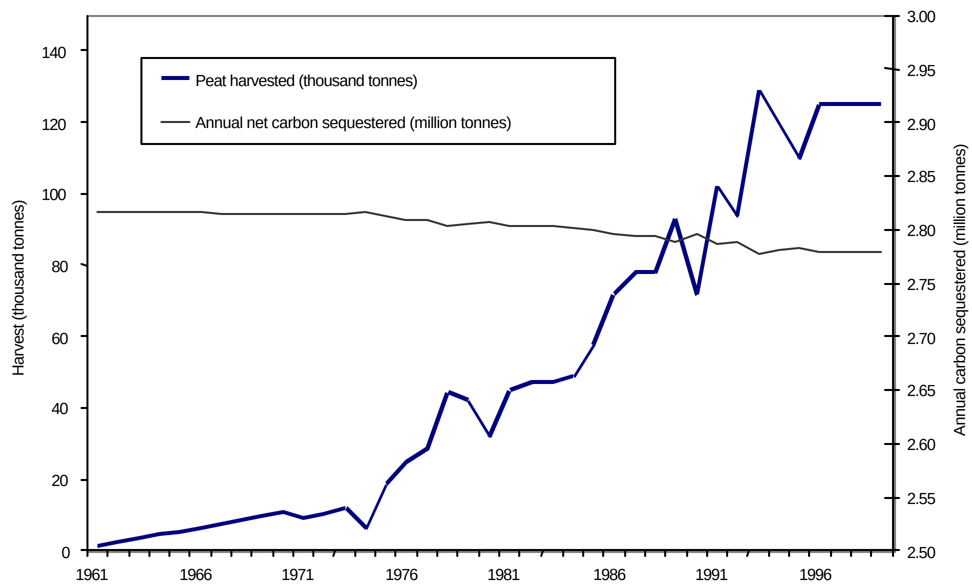
1.2 The State of Alberta's Peatlands

Peatlands are most extensive in the northern two-thirds of the province. They cover nearly 50,000 sq km of the central mixedwood subregion of the boreal forest, which extends across much of northeastern Alberta. According to the 1996 wetland and peatland inventory, peatlands covered 103,200 square kilometres, or 16.3 percent of the Alberta land base. Peatlands play a vital ecological role as a filtration system for water and by controlling water runoff. Peatlands absorb water from spring snowmelt and summer storms, thus reducing flooding, erosion and sedimentation, and recharging the water table in times of drought. They are natural filters, cleansing the water that passes through them. In addition they store a massive amount of carbon. The carbon stored in peatlands increased from 13.64-billion tonnes in 1961 to 13.75-billion tonnes in 1999. However, the annual net rate of carbon sequestration has declined from 2.82-million tonnes in 1961, when there was no harvest, to 2.78-million tonnes in 1996 through to 1999, when the peat harvested was 125,000 tonnes.

Noteworthy

- Peatlands have often been regarded as a hindrance to agriculture. Large areas of peat have been cleared to improve the productivity of agricultural land, but the volume of peat that is cleared is not monitored and has not been included in our account.
- About 3,000 hectares of peat are currently being harvested. The revenue from the peat mined each year in Alberta is about $30-million.
- Estimates for the change in area of peatlands are not available, but the 1996 inventory has been used to estimate the carbon sequestered and the change in area between 1961 and 1999. These estimates are not complete because the losses in peatland due to drainage for agricultural purposes have not been included.
- Peatlands sequester about 0.273 tonnes carbon/hectare/year.
- More carbon is embodied in Canada's peatlands than in our forests.

Net Carbon Sequestration by Peatlands, and Peat Harvested, 1961 to 1999



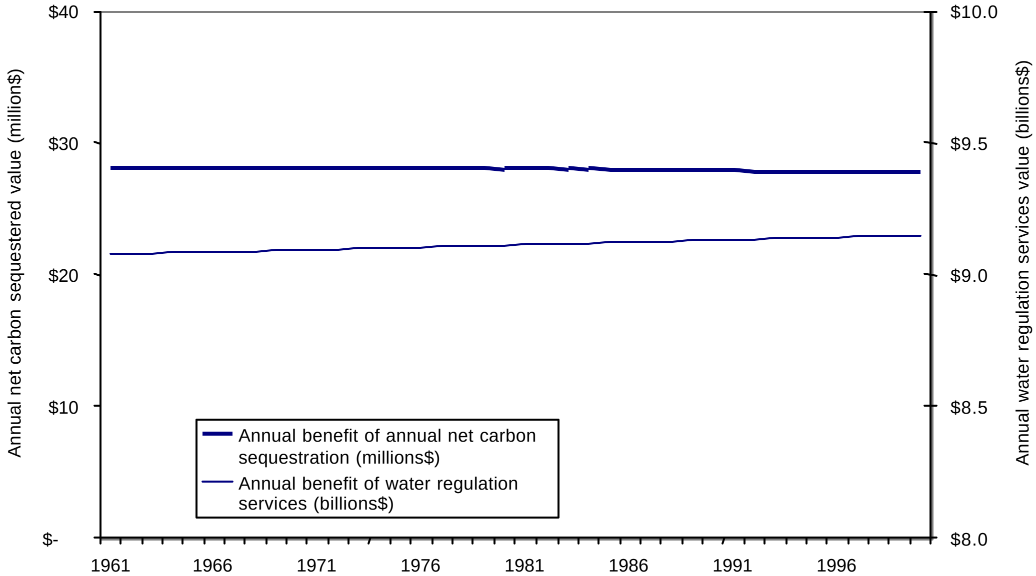
So What?

Peatlands provide two primary ecosystem services: they regulate water flows and they sequester carbon. Studies in Minnesota and North Dakota estimate that the annual benefit of water regulation provided by each hectare of peatlands is $886 (1998$). Based on the peatland area estimated in the 1996 peatland inventory, the water regulation benefits provided by Alberta's peatlands were $9.14-billion in 1996 (1998$).

Because we do not know the original extent of peatland area, a peatland model was constructed based on the estimated annual carbon sequestered by peatlands and the volume of peat harvested per year in Alberta. Using this model, we can estimate the benefits of carbon sequestration and water regulation services provided in 1961, and compare them with the services provided today (see figure below). If we assume that the benefit of avoided damage for each tonne of carbon is worth $10 ($38/tonne of CO_2 x 0.273, the content of carbon in one tonne of CO_2), then in 1961, the benefit of net annual carbon sequestered by peatlands was worth $28.17-million (1998$). In 1999, the net annual carbon sequestered declined slightly and was worth $27.79-million (1998$). The cost of the annual loss in net peatland carbon sequestration was an estimated $387,750 in 1999 (1998$), relative to the net annual carbon sequestered in 1961, when there was no peat harvested. At the same time, the benefit of the overall water regulation services provided in 1999 was an estimated $9.15-billion (1998$). However, the cost in terms of the net annual rate of water regulation services relative to 1961 was an estimated $25,570 (1998$).

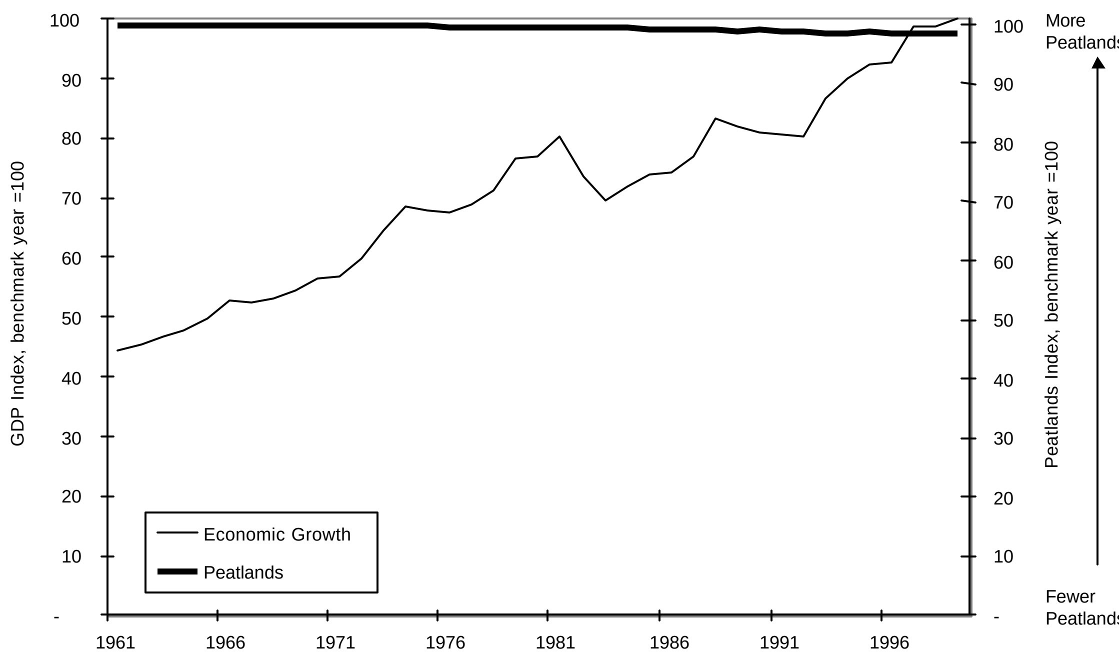
The cost of the annual loss in net peatland carbon sequestration was $387,750 (1998$) in 1999, relative to the net annual carbon sequestered in 1961. The cost in terms of the net annual rate of water regulation services relative to 1961, was $25,570 (1998$). Thus the total cost of lost peatlands between 1960 and 1999 was $413,320 (1998$). Despite these costs, the benefit of the overall water regulation services of existing peatlands in 1999 was $9.15-billion (1998$) and the benefit of carbon sequestration of existing peatlands in 1999 was $27.79-million (1998$).

The Annual Estimated Benefits of Alberta's Peatland Ecosystem Services, 1961 to 1999



Annual value of net carbon sequestration based on $10 per tonne of carbon.The carbon value is based on the avoided damages of climate change and health costs of a tonne of CO2 adjusted by the carbon content in a tonne of CO2 (0.273). The annual value of water regulation services provided by a hectare of peatlands is $866 .

Alberta's Peatland Index: Where are we today?



2. Peatlands and Wetlands

> *Wetlands are one of the earth's most precious land resources. ...Wetlands buffer the effects of floods, storms, and droughts, purify the water of entire watersheds, provide habitat for thousands of plant and animal species, and use energy with an efficiency that rivals the most productive croplands. (Alberta's Wetlands: Water in the Bank! A Discussion Paper prepared for the Alberta Conservation Strategy Project, Environment Council of Alberta, October 1990, p.1)*

Wetlands play an important ecological service in terms of water regimes and habitat for wildlife. Both peat and non-peat wetlands absorb water from spring snowmelt and summer storms, reducing flooding, erosion and sedimentation and recharging the water table in times of drought. They are natural filters, cleansing the water that passes through them. All wetland types are habitat for a wide variety of plants and wildlife, including rare and endangered species. Not least, they provide extensive areas for consumptive and non-consumptive recreation, including hunting, sport fishing and bird-watching. Many of these recreational pursuits are focused on the non-peat wetlands.

Wetlands usually refer to peatlands and non-peat wetlands, but it is important to distinguish between the two. Peat is formed under wet anaerobic conditions and covers large areas of the northern part of the province. Non-peat wetlands, often simply described as wetlands, include sloughs, marshes and areas of shallow sheetwater, which may be permanent or non-permanent. They are found primarily in the southern part of Alberta, where conditions do not favour the accumulation of peat.

The most comprehensive study of peatlands and wetlands is provided by the Peatland Inventory of Alberta.[1] In the inventory, aerial photographs were used to create digitalized maps. Peatlands and non-peat wetlands were identified for the entire province except the Grassland Natural Region. According to the inventory, peatlands covered 16.3 percent (103,200 sq km) of the Alberta land base and wetlands (outside the Grassland Natural Region) a further 1.5 percent (10,400 sq km). The area of wetlands within the Grassland Region is estimated at 4 percent of the region's area, or 3800 sq km.[a] Therefore, the total area of non-peat wetlands is 14,200 square kilometres, and the grand total of peatlands and wetlands in Alberta, is approximately 117,400 square kilometres, or about 18 percent of the province.[b]

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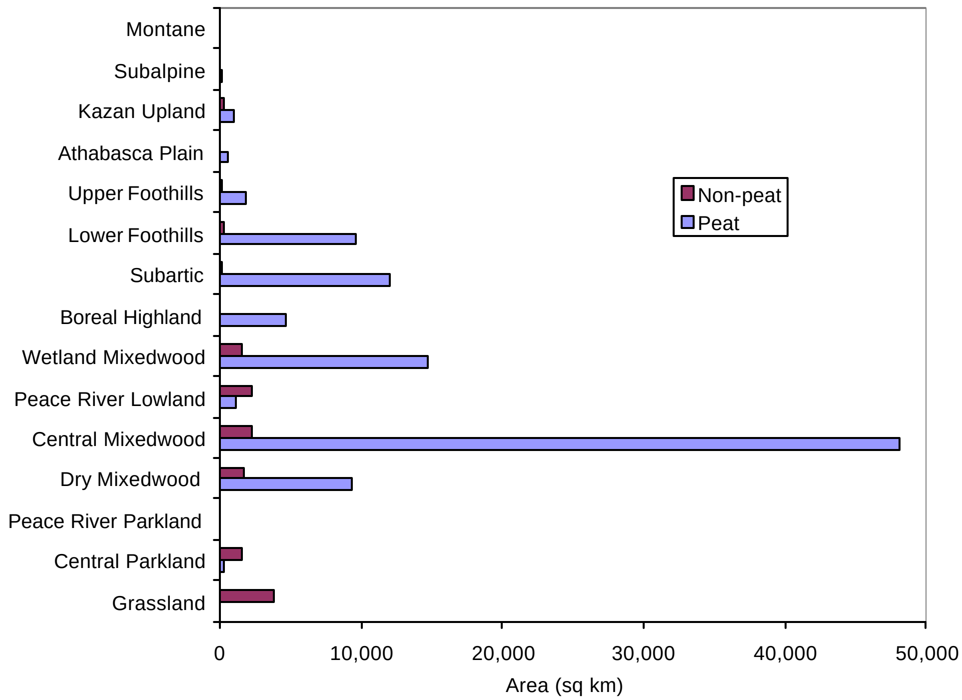
[a] The total area of the Grasslands Natural Region is 96,425 sq km. Wetlands cover less than five percent of this area (1996 State of the Environment Report: Aquatic Ecosystems, Alberta Environmental Protection, p.14). Assuming that five percent of the area is wetlands, gives 4821 sq km of wetlands in the Grassland Natural Region. A figure of 2551 sq km (2.6 percent of grassland region) was derived from figures in *Characterization of Wetland in the Settled Areas of Alberta*, Strong, W.L. (Ecological Land Surveys Ltd.) and Calverley, B.K., A.J., Richard, and G.R. Stewart (Ducks Unlimited Canada), 1993, unpublished report prepared for Alberta Environmental Protection, Table 7, but the authors considered this "a rough estimate and probably an underestimate of the total wetland area" (p.112). In the current publication the wetland area in the Grassland Natural Region is taken at four percent of the total area, an approximate median between Strong and Alberta Environment.

[b] The Peatlands Inventory estimate is considerably below the 1988 estimate made by the Canadian Wildlife Service in *Wetland of Canada*, National Wetlands Working Group, Sustainable Development Branch. Ecological Land Classification Series, No. 24. Environment Canada. That report estimated that peatlands and wetlands covered 137,040 sq km, which is nearly 21 percent of the total area of Alberta. However, the Peatland Inventory is considered to be the most detailed survey.

Peatlands are most extensive in the northern two-thirds of the province, as Figure 1 shows. Peat covers nearly 50,000 square kilometres (more than 30 percent) of the central mixedwood subregion of the boreal forest, which extends across much of northeastern Alberta.

Figure 1: Peatlands and Non-peat Wetlands in Alberta, 1995



Source: Peatlands Inventory of Alberta, Vitt, D.H. et al , (1996) except for Grassland Natural Region. For Grassland Region, see explanation in text.

3. Peatlands

Peatlands play a vital ecological service, both as a filtration system for clean water and as a massive store of carbon. Indeed, there is more carbon embodied in peatlands than in forests or other biomass. Peatlands are typified by the accumulation of organic materials in wet, anaerobic conditions, with the actual nature of the water supply creating a distinction between bogs and fens.[c] Typically peatlands have at least 40 centimetres of carbon accumulation and western Canada peatlands continue to act as net carbon sinks.[2] With increasing concerns about global climate change, this role may soon be given an economic value, especially as development pressures threaten to reduce the extent of peatlands. Although climate change may cause drying at the southern edge, reduction in the permafrost area further north may allow new accumulations of carbon, as vegetation growth increases with the decline of permafrost.[3] However, the drying out of the land, that occurs when permafrost melts may reduce the rate of carbon accumulation.[4]

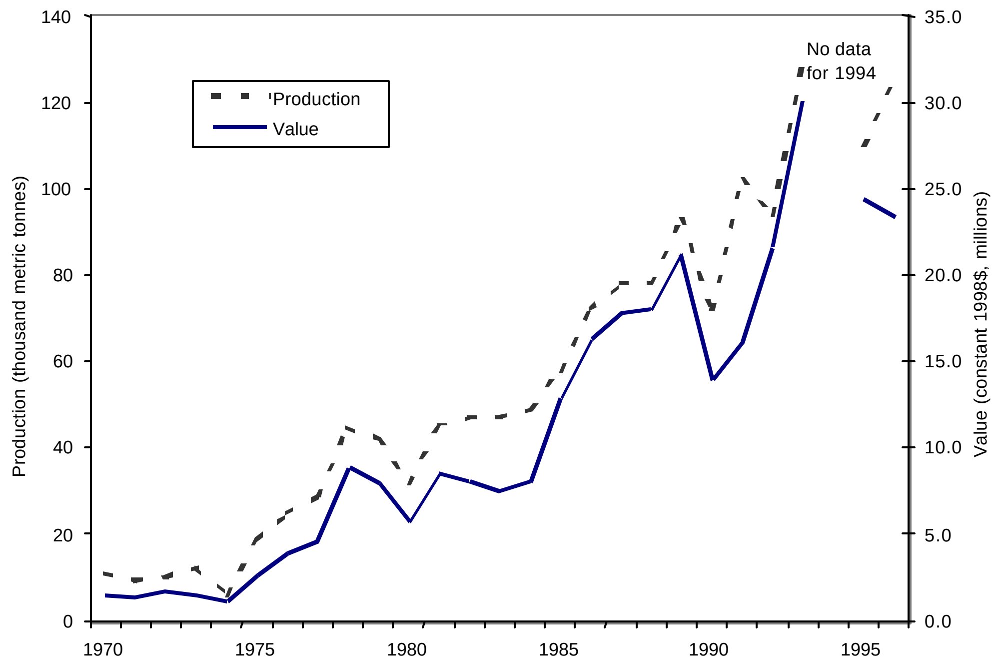
[c] Bogs receive water only from precipitation; fens are influenced by ground or surface water that may be rich in mineral elements.

3.1. The Economic Value of Peatlands

Canadian peat is one of the main ingredients underpinning a multi-billion dollar horticultural industry in North America. On a local basis, the peat industry in Alberta has made a positive contribution to the economy of four rural areas in the province: Athabasca, Seba Beach, Vilna and Newbrook. In 2000, the industry employed approximately 60 full time and 250 seasonal workers, paying total salary and wages of more than $4-million. Using a multiplier effect of 2.17, the industry was responsible for injecting a total of $8.6-million into the communities over the year.

Peatlands supply sphagnum peat material for energy, sorbents and horticultural peat products. The commercial production of peat has increased dramatically since the early 1970s (Figure 2). In 1970, 10,900 tonnes of peat were harvested, rising to 125,000 tonnes in 1996. The current annual revenues from the peat mined in Alberta each year are about $30-million.[d]

Figure 2: Peat Production in Alberta, 1970 to 1996



Source:Canada's Mineral Production Preliminary Estimates, Statistics Canada

The economic value of peatlands was the reason the Peatland Inventory of Alberta was conducted. The Alberta Peat Task Force was set up at the request of the Alberta Peat Moss Harvesters Association, to assist the Alberta government in land use decisions. In addition to identifying the most suitable sites for extraction, the inventory drew attention to sensitive sites for possible preservation.

[d] Statistics Canada does not publish current production data for Alberta for confidentiality reasons, as there are only two major producers.

Even in remote areas, human activity has affected peatlands. For example, in a 12,500 sq km area east of Wabasca and north of Lac La Biche (in the Alberta Pacific Forest Management Agreement area), almost 40 percent of the area is peatlands. Despite the unfavourable access almost 0.6 percent (30 sq km) of the peatland area has been disturbed by seismic lines.[5] If 50-metre buffers along the lines are included, nearly two percent (99 sq km) of the area has been affected. This fragmentation can have a considerable impact on wildlife and may affect the drainage of the peatlands.[6]

Peatlands are used as a resource for commercial peat production, but often peatland has been regarded as a hindrance to agriculture. In the past, large areas of peat were cleared each year and burned to improve the productivity of the land, but the burning of peat on the land is no longer common. The volume of peat that is cleared and burned each year is not monitored. In the absence of data on peatland clearing for agricultural expansion, a more complete peatland account is not possible, thus our estimates of peatland area remaining are likely low and our estimates of carbon sequestration by peatlands are likely high.

When Drayton Valley Power considered operating a biomass generating plant in the Westlock area, they commissioned a study of the peat resources in the area. If the power plant were run entirely on peat, it would require 330,000 wet tonnes per year. It was found that there was enough peat within 10 km of the plant to last for 100 years.[7] This plant is not currently operating and there is no other peat-fired generating plant in Alberta. However, the Westlock peat study gives a general idea of the large amounts of peat that exist.

3.2. The Ecological Value of Peatlands

Peatlands are ecologically important because they control water runoff during storms, reduce soil erosion, adsorb and hold contaminants, and store carbon. They control water flow by soaking up flood and meltwater, then releasing the water more slowly. Peatlands also convert accumulated plant materials to peat, which stores, or sequesters, the carbon. Indeed, peatlands are estimated to store an amount equal to about three percent of the carbon dioxide emitted in Alberta.[8] The 1996 *Peatland Inventory of Alberta* reported the approximate area of peatlands to be 10.32-million hectares.[9] Based on this area, the peatlands of Alberta contained an estimated 13.74-billion tonnes of carbon in 1996.[e]

To estimate the change in carbon storage and net carbon sequestration between 1961 and 1999, several steps were taken:

- Using the 1996 peatland inventory area, the carbon storage (i.e., stock) was calculated using a conversion formula developed by Gorham (see footnote e). In 1996, the estimated carbon stored in Alberta's peatlands was 13.74 billion tonnes.
- In order to back-cast the carbon accounts from 1996 to 1961, the previous year's peatland carbon storage was estimated by subtracting one year of carbon sequestration based on the peatland area multiplied by the estimated annual carbon sequestration rate (0.273 tonnes carbon/hectare/year),[10] and then adding the carbon content of the dry mass of peat harvested in that year (carbon content of dry mass = 0.517). The tonnes of peat harvested are given with 40 percent moisture content, thus the carbon content was calculated using

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[e] Calculated as follows: area of peatland x 10,000 m^2/ha(conversion factor) x 2.3 m (depth of peat) x 112x103 g/m^3 (mean bulk density of peat) x 0.517 (carbon content of dry mass). The source for this calculation is Gorham, E (1991). "Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming." *Ecological Applications*, 1(2): 182-195.

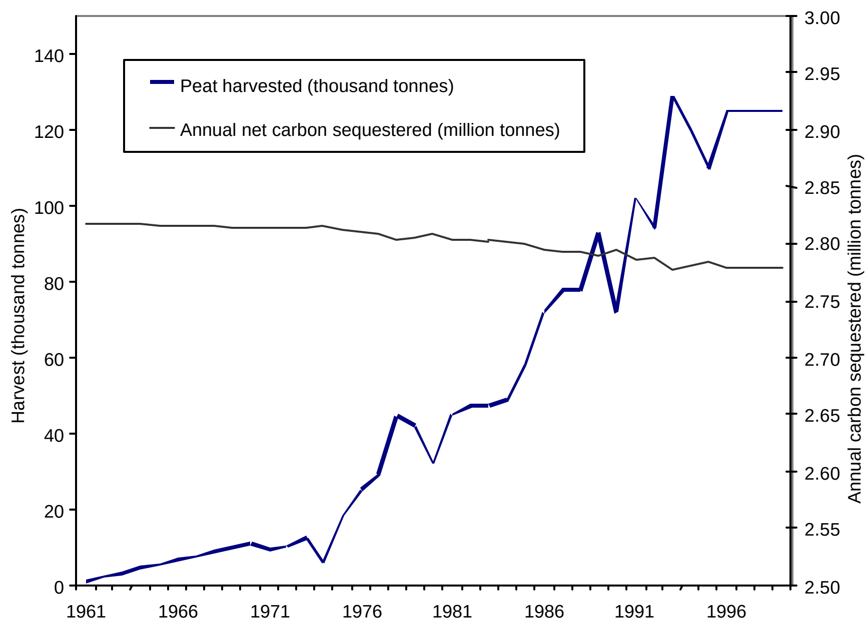
60 percent of the annual weight harvested. This provides an estimate of the carbon stored in peatlands in the previous year.

- The peat harvested was extrapolated from the earliest reported date (1970) when the harvest was 11 thousand tonnes, back to 1961 using regression, assuming that in 1960 there was zero harvest.
- The Gorham conversion formula was then used to derive the area of peatlands in the previous year from the estimated carbon stored in Alberta's peatlands as explained above.
- This was repeated for each year back to 1961.

Thus, we estimate that in 1961 Alberta's peatlands stored about 13.64 billion tonnes of carbon. By 1999, we estimate the carbon stored in peatlands had increased by 106.45 million tonnes to 13.75 billion tonnes, assuming the estimated constant for annual carbon sequestration rate (0.273 tonnes carbon/hectare/year), and the same peat harvest as 1996 (125,000 tonnes which converts to 40,000 tonnes of carbon).

However, despite an estimated increase in the total volume of stored carbon, we estimate that the annual net rate of carbon sequestration has declined very slightly from 2.82 million tonnes of carbon per annum in 1961 (when there was no harvest) to 2.78 million tonnes per annum in 1996 through to 1999, when the peat harvested was 125,000 tonnes (estimated for 1997 to 1999; see Figure 3). This decline may be overestimated at this time because of the simple carbon accounting model we developed and the assumptions we made. For example, our model assumes that all carbon from the peat harvested each year is released to the atmosphere, and results in a direct decrease in the carbon stored. More sophisticated carbon accounts would factor in carbon retained in the form of horticultural peat in Alberta gardens as well as account for the "export" of carbon contained in peat to other provinces or international markets. On the other hand, the carbon accounts underestimate the loss of carbon due to lack of data and information on the extent of agricultural clearing of peatlands. In future, more sophisticated carbon accounting should attempt to correct for these deficiencies related to peatlands.

Figure 3: Annual Net Carbon Sequestered by Alberta's Peatlands and Peat Harvested, 1961 to 1999

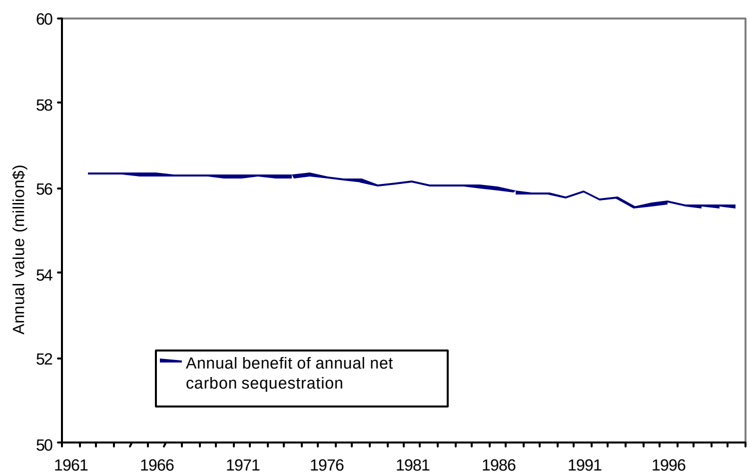


It is estimated that the 125,000 tonnes of peat harvested in 1996 came from approximately 3,000 hectares of peatlands.[f] Horticultural peat production can continue at one site for about 20 years before all the peat has been extracted and the land is reclaimed. Each year the area reclaimed is about 150 hectares (total area in production equals 3000 hectares, divided by 20, which is the length of time a site can be in use =150 hectares). When the land is reclaimed back to sphagnum peat, sphagnum will grow about 10-12 centimetres in a year. However, this will only create about 1-2 millimetres of peat a year, or about 10 centimetres per century. It will be many hundreds of years before a site can be worked again. But given the fact that the current area going out of production each year is less than 0.001 percent (1.5 sq km) of the total peatland area in the province, there would be plenty of time for the peat to regenerate before it was needed for future harvests. This assumes, of course, that climatic conditions remain favourable for the growth of sphagnum at current rates.

In addition, there have been other losses in peatlands due to drainage for agriculture, but no data on these losses are available. The situation with respect to commercial extraction sites that are later reclaimed is different than for peatlands that are cleared for agriculture. When peat is extracted for horticultural use, it continues to sequester carbon and, by improving the productivity of soil where it is incorporated, encourages the growth of plants that sequester more carbon. In the case of agricultural clearing, the peat may be removed permanently and its ecological values lost. However, as we do not know the extent of the agricultural clearing, it is not possible to put an economic value on the ecological services that are lost as a result.

Based on this carbon peatland account, the value of carbon sequestered can be monetized. In 1961, the value of carbon sequestered annually by peatlands was worth an estimated $56.35-million, if we assume that the benefit of avoided damage for each tonne of carbon is worth $20 globally (Figure 4). In 1999, the net annual carbon sequestered declined very slightly according to the peatland carbon model, and was worth $55.57-million. This decline may be overestimated because of the simple model used. Our model assumes that all carbon from the peat harvested each year is released to the atmosphere. On the other hand, there may be an underestimation, also due to a lack of data and information on the extent of agricultural clearing of peatlands.

Figure 4: Annual Economic Benefit of Carbon Sequestration by Alberta's Peatlands, 1961 to 1999

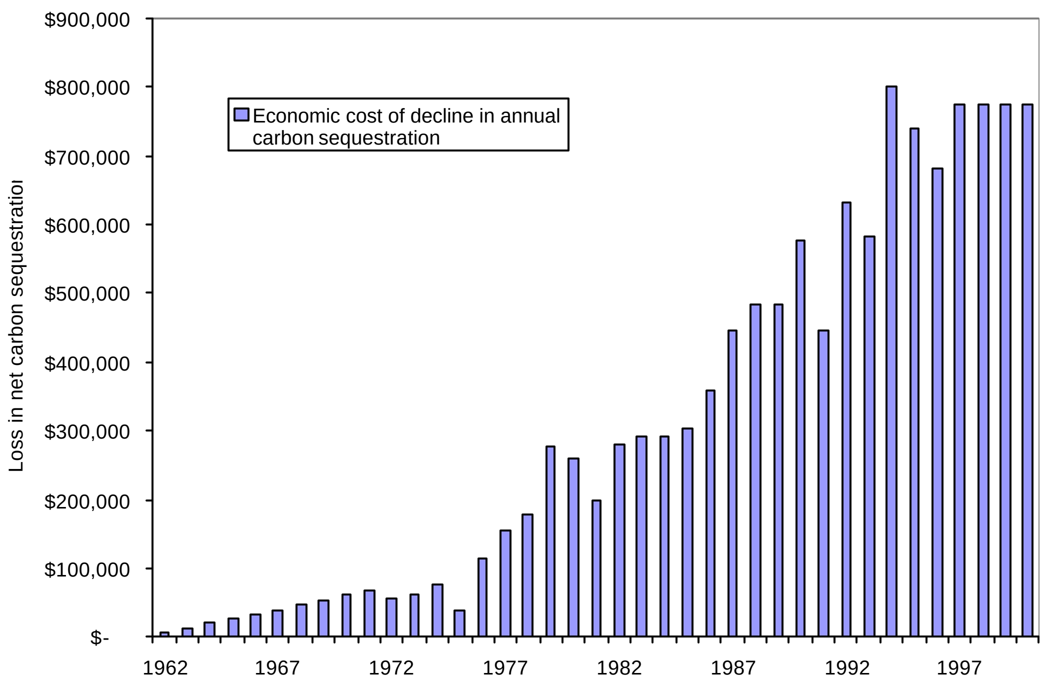


Annual value of net carbon sequestration based on $20 per tonne of carbon for avoided damages of climate change.

[f] Based on current annual production of six million bales and an average yield of 1,000 bales/acre/year.

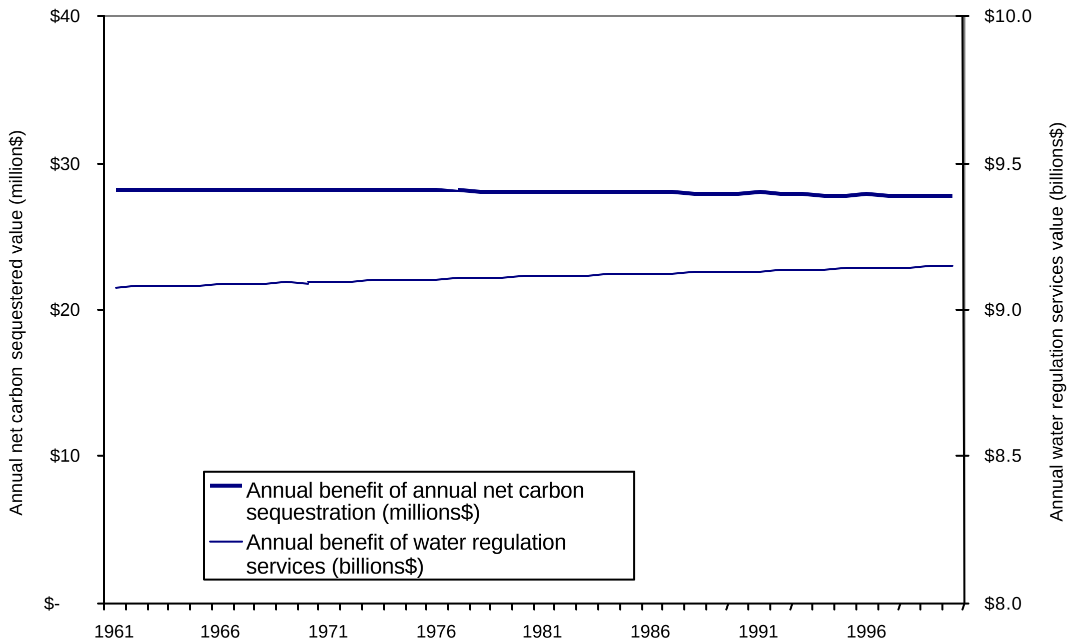
The damage cost of each tonne of carbon emitted is estimated to be at least $20. Therefore, if we assume that a decrease in the annual carbon sequestration by peatlands results in an increase of carbon in the atmosphere, the potential cost of the annual loss in net peatland carbon sequestration was an estimated $6,762 in 1961, and $775,500 in 1999, in relation to the net annual carbon sequestered in 1960, when there was no peat harvested (Figure 5). This is relatively small compared with the economic benefits of peat extraction, which were $30-million in 1999. However, this is only one of many vital ecological services performed by peatlands and thus does not represent the full ecological benefits of Alberta's peatlands.

Figure 5: The Annual Economic Cost due to a Decline in the Annual Net Carbon Sequestered by Alberta's Peatlands, 1961 to 1999



Peatlands also provide water regulation and services. Based on an average value from studies in Minnesota and North Dakota, the annual value for these services per hectare is an estimated $886.[11] Based on the peatland area estimated in the 1996 peatland inventory, the annual value of water regulation by peatlands was estimated at about $9.15-billion in 1999. Assuming there was the area of peatland extrapolated from the peatland carbon account, the annual benefit in 1961 was $9.08-billion (see Figure 6).

Figure 6: Alberta's Annual Peatland Benefits due to Carbon Sequestration and Water Regulation, 1961 to 1999



Annual value of net carbon sequestration based on $10 per tonne of carbon. The carbon value is based on the avoided damages of climate change and health costs of a tonne of CO2 adjusted by the carbon content in a tonne of CO2 (0.273). The annual value of water regulation services provided by a hectare of peatlands is $866 (Sip et al. 1998.

4. Wetlands

In southern Alberta, an estimated 330,000 wetlands cover less than five percent of the total land area.[12] Wetlands in the settled zone of Alberta were once far more extensive than they are today. In earlier times, shallow sloughs or "prairie potholes" were abundant, ranging in size from a fraction of a hectare to several hundred hectares. It is thought that about 60 percent of the sloughs and marshes in the settled area of the province have been lost since European settlement began.[13] Given this estimate, the original extent of wetlands in the settled area of the province would have been about 35,500 sq km, based on the 1996 inventory estimate of about 14,000 sq km.[g]

It has been suggested that approximately half of North America's prairie potholes had been drained by 1950,[14] and it is estimated that settlers had reduced the extent of wetlands in the Canadian Prairie Pothole Region by 1.2-million hectares in Canada by the mid-1970s.[15] A study in the aspen parkland region (north of the true prairie), estimated a 49-percent loss of wetland area by 1950 and 61-percent loss by 1970.[16] Furthermore, a recent report states that by 2000, 71 percent of wetlands in the Prairie pothole region had gone.[17] Losses have been especially great around Edmonton and Calgary. By 1966, between 76 percent and 96 percent of the wetlands

[g] Wetlands cover an estimated 10,400 sq km outside of the Grassland Natural Region, and 3,800 sq. km within the Grassland Region, for a total estimate of 14,200 sq. km in 1996. These estimates are derived from Vitt et al. 1996, plus addition of estimate for grassland region from Strong et al. 1993.

around Edmonton and Calgary had been converted to other uses, and losses have continued over the last 30 years.[18] It is estimated that between 1981 and 1989, 0.5 percent of Alberta's wetlands were lost annually to agricultural drainage.[19] This figure is supported by a detailed study in central Alberta that indicated a 16- to 17-percent decline in the area of wetlands between 1975 and 1987.[20]

Wetlands were traditionally considered an impediment to agriculture and there were various financial incentives to encourage farmers to drain their land.[21] A study of wetlands in the agricultural area of Alberta in the 1980s found that 66 percent of the remaining wetlands had been adversely affected by agriculture, while degradation at the margins (which included haying, clearing, grazing and cultivating) was as high as 93 percent.[22]

It was not until 1990 that the Alberta government recognized the need to conserve wetlands. *Wetland Management in the Settled Area of Alberta: An Interim Policy* was published in May 1993, but it remained a policy with no teeth. Although it was the declared intention "to conserve slough/marsh wetlands in a natural state" and to "mitigate degradation or loss of slough/marsh wetland benefits as near to the site of disturbance as possible," the government relied on education and co-operation from landowners and municipalities to achieve its objectives. Changes in the extent of wetlands since the policy was introduced have not been recorded but Ducks Unlimited and other partners, including Alberta Environment, are exploring the possibility of creating a comprehensive wetland inventory.[23]

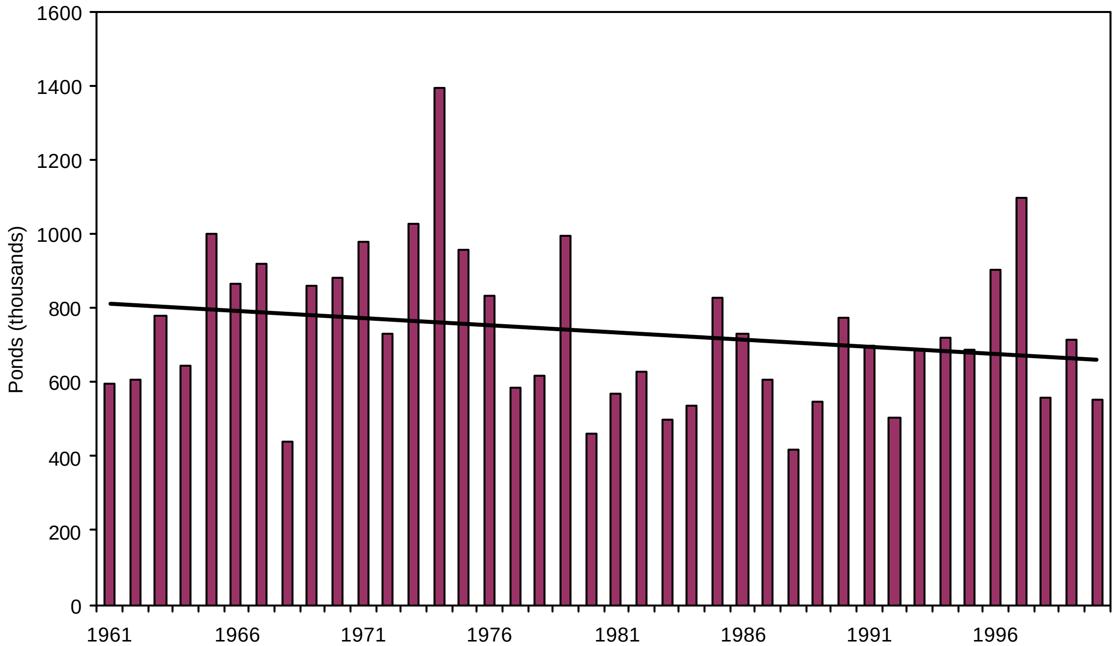
There is increasing concern about the state of wetlands—not only their geographical extent, but also the agricultural impact on water quality. For example, a study conducted in Saskatchewan between 1991 and 1996 found that in three of the six years, between 9 and 24 percent of the wetlands studied had pesticide levels that exceeded the guidelines for the protection of aquatic life.[24] Pesticides in wetlands are of concern to Ducks Unlimited, so the organization joined with Alberta Environment to monitor pesticides in 60 wetlands in Alberta in 2000. The decline in wetlands is an ongoing concern to Ducks Unlimited, as they try to conserve wetlands for waterfowl.

Although there has been a range of estimates, based on local studies, of the decline in wetlands since settled times, no one really knows exactly how much wetland has been lost. One of the problems in tracking current annual changes is how to evaluate wetland loss especially when there are cyclical patterns in the weather. After several dry years, it may appear that the wetland area has decreased, although some wetlands can return following a number of wet seasons.

While there is no accurate measure of the change in wetlands, there are annual surveys of the number of ponds, which are often associated with wetlands. There appears to be a decrease in the number of ponds in southern Alberta[h] between 1961 and 1999, as shown in Figure 7.[i] It is uncertain whether this decline reflects a cycle of dry years or is a permanent long-term decline. Certainly the cumulative loss of wetlands and the long periods of drought that occurred during the 1970s and early 1980s caused waterfowl populations to decline by one-third in the mid-80s.[25] The drought, in turn, also may have accelerated the drainage and cultivation of wetlands, leading to permanent changes.

[h] Southern Alberta includes the settled area of the province from the Edmonton area to the U. S. border.
[i] Ponds counts are part of the annual waterfowl breeding surveys conducted across the prairies and published by the U.S. Fish and Wildlife Service at http://migratorybirds.fws.gov/reports/reports.html.

Figure 7: Number of Ponds in Southern Alberta



Source: Waterfowl Breeding Population Survey.at http://migratorybirds.fws.gov/reports/reports.html

4.1. Ecological Values of Wetlands

In 1988, the value of Canada's wetlands was estimated to be $5- $10-billion.[26] This includes a wide variety of ecological functions performed by wetlands, including their capacity to protect shorelines and watersheds from erosion, their contribution to improved water quality in many of the nation's watersheds, their value in supporting coastal and inland fisheries and the habitat they provide for waterfowl as well as their use for wild rice production, recreation and for educational purposes. By 2000, the value of Canada's wetlands was estimated at $20-billion.[27] Assuming that 11 percent of the wetlands are in Alberta[28] the value of all Alberta's wetlands, including peatlands, may be about $2-billion, based on the above estimate.[j]

An Alberta study estimated that just the drainage of the non-permanent wetlands of the five northern river basins would reduce waterfowl populations in the area by 80 percent (i.e., a loss of 9.1 million ducks)—or 54 percent of the total provincial duck population. The present cost of draining that area over 100 years would be $1.6-billion, of which $850-million would be for wildlife habitat mitigation, $375-million for off-farm drainage works and $330-million for on-farm drainage.[29] While the on-farm drainage costs might result in increased agricultural production, the off-farm costs would be a cost to society and wildlife. The study concluded that while from a farmer's perspective it can be financially attractive to drain non-permanent wetlands, from a public perspective, wetland drainage is only economically feasible if the wildlife

[j] 11 percent of $20-billion is $2.2-billion.

habitat mitigation costs are not included, erosion control costs are low, or non-permanent wetlands are abundant.

Various attempts have been made to put a value on specific wetland types, but the values vary greatly according to location. "Published wetland values have ranged from $299 per hectare for South Dakota seasonal wetlands … to $6,669 per hectare per year for Louisiana coastal wetlands … and to $23,465 per hectare for Charles River wetlands …."[30]

As Leitch and Ekstrom pointed out in 1989, "A number of complicating factors contribute to the valuation problem. Primary among these are the gaps in knowledge, both natural and social, that is necessary for understanding and valuing wetlands. For example, economists have not yet agreed on just how to consistently and unequivocally estimate aesthetic values held by individuals. Also, waterfowl biologists have been reluctant to estimate changes in waterfowl populations that would result from marginal changes in prairie potholes. These gaps exacerbate the difficulty of conducting multidisciplinary research. These problems are not unique to wetlands … but they are perhaps nowhere more complex."[31]

The non-peat wetlands, found in the southern half of Alberta, are part of the Prairie Pothole Region that extends from Alberta through southern Saskatchewan and southwestern Manitoba to North and South Dakota and Minnesota. "Estimates of the human-based values of wetlands range from negative to priceless… Some prairie potholes have been estimated to be valued at well over $1,000 per acre … while others have been estimated to have negative values for some functions, such as water quality or as a disease vector …"[32] The best approximation for the value of the Alberta section can be derived from studies in North Dakota and Minnesota.

The first attempt to put an economic value on specific wetlands in the Prairie Pothole Region was published in 1994.[33] The study states that, "The range of wetland values should not be generalized as the value for all other wetlands in the Prairie Pothole Region. Wetlands that look just like any of the study wetlands may have different values due to differences in their locations relative to flood plains, aquifers, waterfowl flyways, other wetlands and other topographical features of the landscape or because of different intensity of use by wildlife or people."[34] However, the general conclusions from this North Dakota study are relevant for prairie potholes in Alberta.[35]

Another study, relating to the same data points out that "Estimated values for these five prairie potholes appear to differ widely from estimated values of wetlands in the literature. This may be due to these being marginal and not average values, the abundance of prairie pothole wetlands in the study area, or one or more of the other reasons cited above."[36]

A study of the dollar values for northwest Minnesota wetland functions averages various values calculated in previous studies, as shown in Table 1.[37]

Table 1: Average Per Acre Dollar Value for Northwest Minnesota and North Dakota Wetland Functions

Wetland function	Per acre value (US$1996)	Per hectare value (CDN$1998)
Wildlife Habitat	$6	
Fishery Habitat	$8	
Flood and Storm water	$256	
Water Quality	$175	
Shoreline[k]	$2950	
Groundwater	$564	
Aesthetics, Recreation, Education	$26	
Commercial Uses	$21	
Total without shoreline protection	$1,035	$3,582
Total including shoreline protection	$3,985	$13,790

Source: see text

How applicable are these values to Alberta? Given that these estimates are a mean value of the estimated dollar values from several other studies, they moderate the high and low estimates apparent across various Minnesota and North Dakota studies. In addition, we know that wetlands may provide the same basic services and benefits regardless of their location. For example, a study of wetlands in central Alberta noted that, "socio-economic and environmental values derived from wetlands are numerous and include specifically wildlife habitat, flood control, groundwater recharge, water clarification, consumptive and non-consumptive recreational use, conservation of surface water, agricultural forage production and water supply, prevention of soil erosion and water for human consumption."[38]

In fact, the value of Alberta's wetland wildlife habitat may be higher than average. Waterfowl breeding population densities and productivity have traditionally been higher in the prairie-parkland region of Alberta than in any other major production area of the continent. "Alberta annually supports upwards of 20 and 25 percent of the surveyed continental breeding duck and mallard populations respectively."[39]

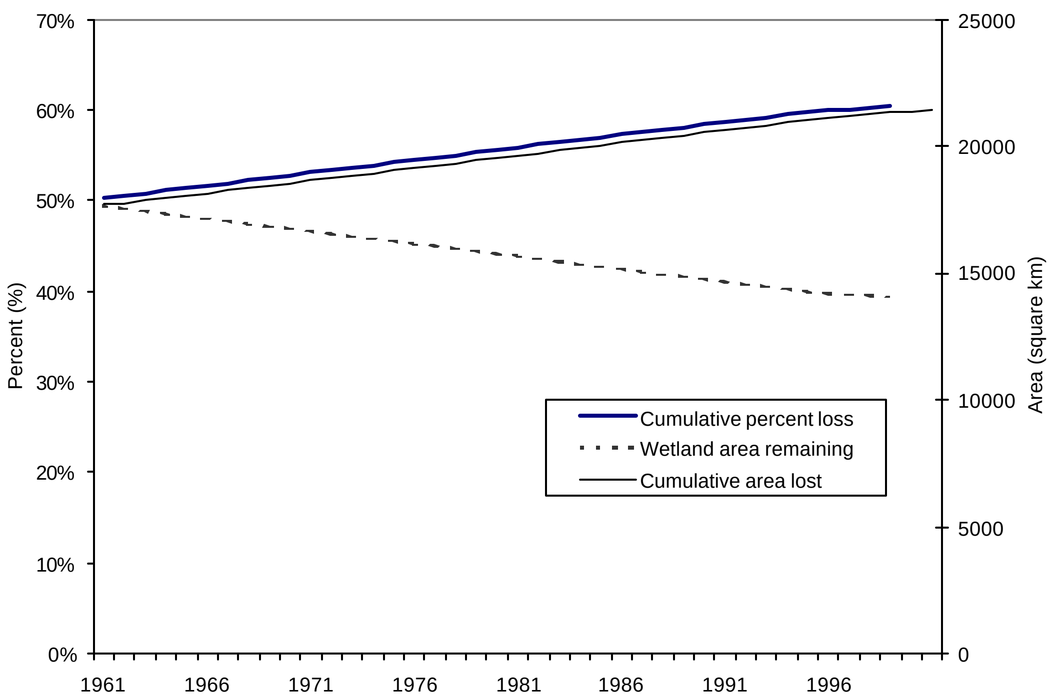
Another study recognizes the importance of wetlands regarding the control of water flows in Alberta. "Control of drainage flow releases at the farm level significantly reduces off-farm drainage costs by reducing peak downstream flows. Capital costs for uncontrolled flows are up to 4.6 times greater than those for controlled. Unless drainage control at upstream locations is incorporated in future programs, the economics of drainage may be seriously affected."[40]

[k] The shoreline value was based on the cost of vegetative plantings of a shoreline and first year maintenance. It is excluded in the first valuation because the level of shoreline protection provided by all wetlands in Alberta is unknown. As a result, we have opted for the more conservative approach.

4.2. Cost of the Decline in Alberta's Wetlands

Several studies have been reviewed in the above section, of which the key estimates are presented here. It has been estimated that, by 1950, approximately 50 percent of the prairie pothole wetland area present in pre-settlement times had been drained in North America.[41] Similarly, a study in Alberta's aspen parkland region estimated a loss of 49 percent of the area of wetlands by 1950.[42] Subsequently, the *1996 Alberta State of the Environment Report* estimated that 60 percent of wetland area had been lost by 1996. We used these estimates to indicate the cumulative percentage of wetlands, relative to pre-settlement wetland area in Alberta, that have been lost (Figure 8). The percentage lost each year was evenly distributed between 1961 and 1996, with an estimated 0.28 percent lost per year. No data or estimates are available for 1996 to 1999, so we estimated that the annual percentage of wetland area lost reduced by half to 0.14 percent.

Figure 8: Estimated Percentage of Wetland Area Lost since Pre-settlement and the Area Remaining in Alberta, 1961 to 1999



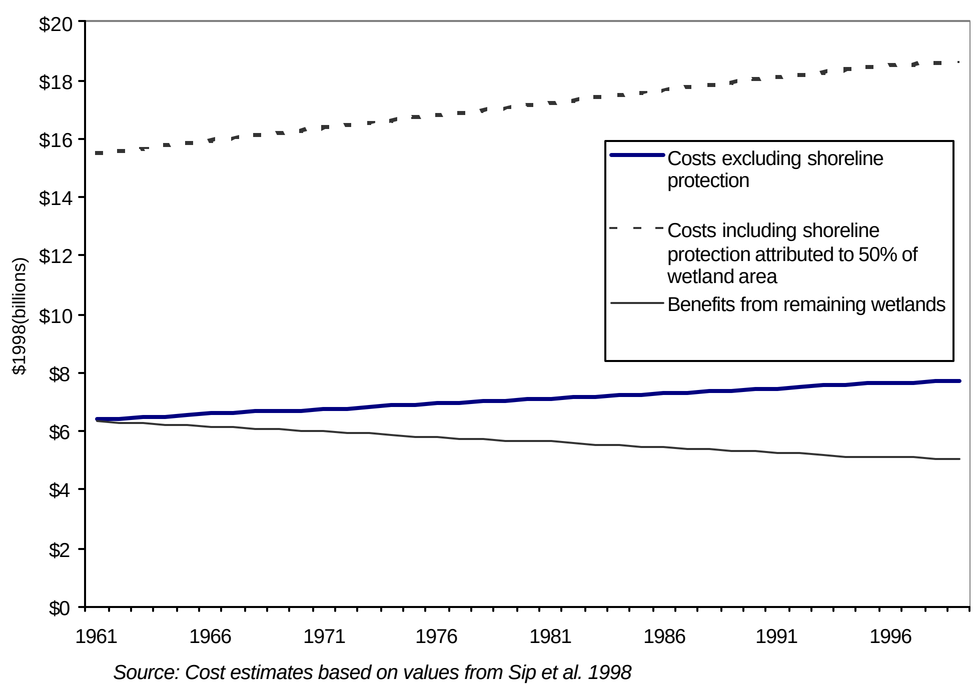
Source: Estimates based on1996 Alberta State of the Environment Report

Based on these estimates, 17,750 square kilometres (50 percent) of Alberta's wetlands had been lost by 1960, 21,300 square kilometres (60 percent) by 1996, and 21,449 square kilometres (60.42 percent) by 1999. The area remaining in 1996 was an estimated 14,200 sq km, and in 1999 an estimated 14,051 sq km.

Using the estimated costs of the services (i.e., ecosystem functions) lost when wetlands are drained and lost due to development of roads, agriculture or other types of land use, we can estimate the annual cost for the losses sustained in Alberta. There are no direct estimated values for the province of Alberta's wetlands, however, the average values based on several studies in Minnesota and South Dakota, were compiled by Sip et al. 1998.[43] They used simple averages of dollar values from secondary sources as proxies for the economic values of wetland functions. These values are: wildlife and fish habitat; control of flood and storm water; water quality; shoreline protection; groundwater; and aesthetics, recreation and education (see Table 1). The dollar value estimated for commercial use (e.g., hay production) was excluded, and shoreline protection was only included in a second estimate, assuming only 50 percent of the total wetland area provided substantial shoreline protection.

Thus, the estimated dollar value used to calculate the annual cost of lost wetlands is $3,582 (1998$) per hectare ($1,449 per acre), and the additional estimated dollar value for the loss of shoreline protection provided by 50 percent of the lost wetland area is calculated using an annual cost of $10,208 (1998$) per hectare ($4,131 per acre). In comparison, Costanza et al. estimated that wetlands provide ecological services worth $21,313/hectare (CDN$1998; $14,785 in 1994 US dollars) on an annual basis.[44] Figure 9 shows the annual cost for the lost wetland functions as well as the annual benefit of the remaining area of wetlands.

Figure 9: Estimated Annual Economic Cost of the Losses in Wetland Services Due to a Decrease in Wetland Area in Alberta, 1961 to 1999 (1998$)



The annual cost due to the estimated cumulative loss of 50 percent of Alberta's wetlands in 1960 was an estimated $6.4-billion (excluding shoreline protection services). By 1999, when the estimated cumulative loss of wetlands was 60.3 percent, the estimated annual cost was $7.7-billion. If we assume that 50 percent of the lost wetland area provided shoreline protection services, then the estimated annual cost was about $15.5-billion in 1961, and $18.6-billion in

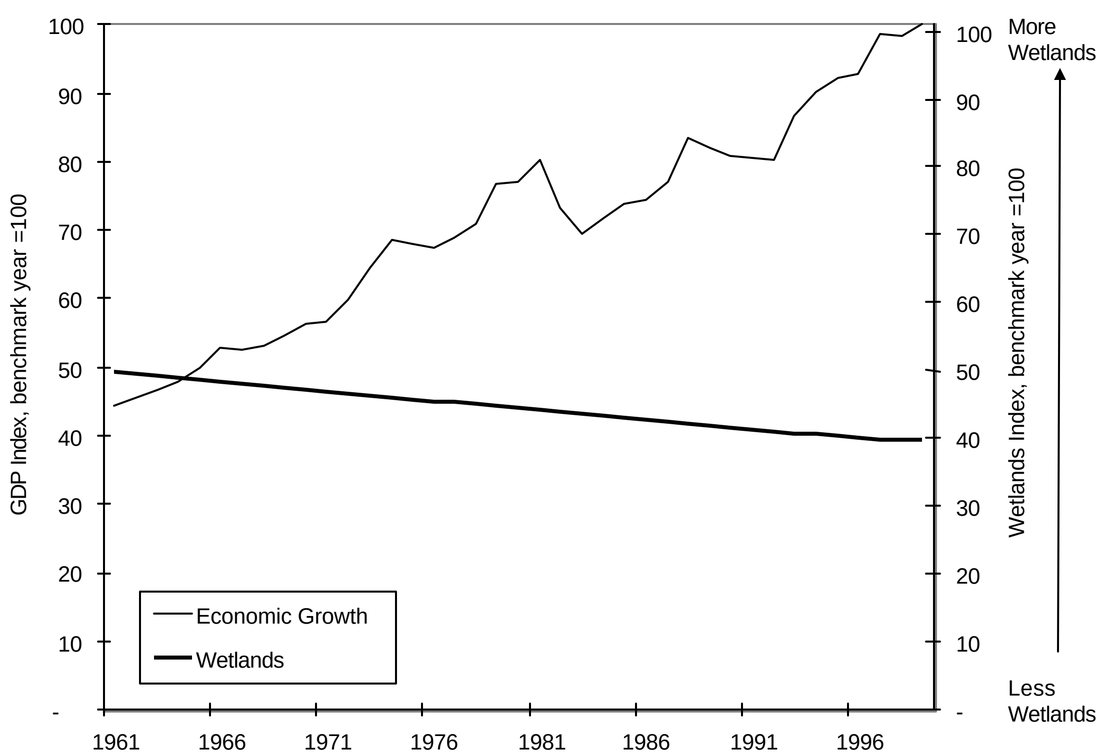
1999. If the annual value per hectare estimated by Costanza et al. is used, then the costs range from $38.0-billion in 1961 to $45.7-billion in 1999.[45]

The benefit of the flow of ecological services from Alberta's remaining wetland areas was an estimated $6.3-billion in 1961, decreasing to about $5.0-billion in 1999, due to the losses described above (excluding the shoreline protection). If we apply the higher per hectare annual value established by Costanza et al., then the value of ecological services in 1961 would be $37.83-billion, and $29.95-billion in 1999.[46]

5. Wetland and Peatland Indices

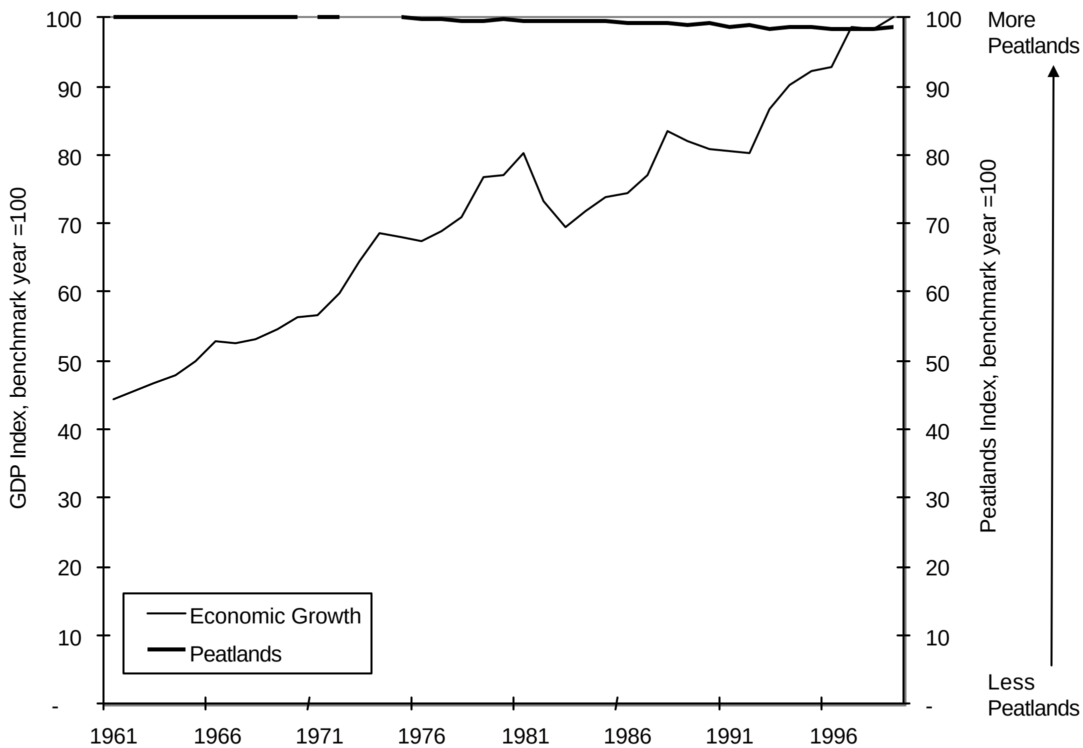
To construct a GPI index for wetlands, the estimated original area, approximately 35,500 square kilometres, was adopted as the benchmark (100 on the index). Zero on the index represents zero square kilometres of wetlands. In 1961, the status of Alberta's wetlands was 49.7, and by 1999, the index had dropped to 39.6 (Figure 10).

Figure 10: Wetland Index, 1961 to 1999



To calculate the peatland index, we used the net annual carbon sequestration rate from the peatland carbon account, which deducts the carbon released due to the commercial peat harvested. The steps taken to estimate the account are described in the peatland section above. As noted above, it is assumed that all the carbon in the peat harvested is released to the atmosphere, and thus the decline in net peat carbon sequestered may be overestimated. However, the exclusion of peatland clearing for agriculture due to a lack of available data means that the change in carbon sequestration and storage may be underestimated . As better information becomes available this index will be updated accordingly. In the meantime, based on the peatland carbon account, the index uses 1961 as the benchmark year (100 on the scale), when the net annual carbon sequestered was highest (2.817 million tonnes of carbon sequestered), because there was no peat harvested. In 1999, the index was 98.64 (Figure 11).

Figure 11: Peatland Index, 1961 to 1999



Appendix A. List of Alberta GPI Background Reports

A series of Alberta GPI background reports accompanies the *Alberta Sustainability Trends 2000* report and this report. These documents are being released in late 2001 and early 2002 and will be available on the Pembina Institute's website at www.pembina.org.

Alberta GPI Background Reports and Sustainability Indicators

GPI Background Reports	GPI Accounts Covered by Report
1. Economy, GDP, and Trade	• Economic growth (GDP) • Economic diversity • Trade
2. Personal Consumption Expenditures, Disposable Income and Savings	• Disposable income • Personal expenditures • Taxes • Savings rate
3. Money, Debt, Assets and Net Worth	• Household debt
4. Income Inequality, Poverty and Living Wages	• Income distribution • Poverty
5. Household and Public Infrastructure	• Public infrastructure • Household infrastructure
6. Employment	• Weekly wage rate • Unemployment • Underemployment
7. Transportation	• Transportation expenditures
8. Time Use	• Paid work time • Household work • Parenting and eldercare • Free time • Volunteerism • Commuting time
9. Human Health and Wellness	• Life expectancy • Premature mortality • Infant mortality • Obesity
10. Suicide	• Suicide
11. Substance Abuse; Alcohol, Drugs and Tobacco	• Drug use (youth)
12. Auto Crashes and Injuries	• Auto crashes
13. Family Breakdown	• Divorce
14. Crime	• Crime
15. Gambling	• Problem gambling
16. Democracy	• Voter participation
17. Intellectual Capital and Educational Attainment	• Educational attainment
18. Energy (Oil, Gas, Coal and Renewable)	• Oil and gas reserve life • Oilsands reserve life
19. Agriculture	• Agricultural sustainability
20. Forests	• Timber sustainability • Forest fragmentation

GPI Background Reports	**GPI Accounts Covered by Report**
21. Parks and Wilderness	• Parks and wilderness
22. Fish and Wildlife	• Fish and wildlife
23. Wetlands and Peatlands	• Wetlands • Peatlands
24. Water Resource and Quality	• Water quality
25. Energy Use Intensity, Greenhouse Gas Emissions and Air Quality	• Energy use intensity • Air quality-related emissions • Greenhouse gas emissions
26. Carbon Budget	• Carbon budget deficit
27. Municipal and Hazardous Waste	• Hazardous waste • Landfill waste
28. Ecological Footprint	• Ecological footprint

Appendix B. Wetlands and Peatlands Data

Wetlands and Peatlands Data, Indices and the Cost of the Loss of Wetlands

Year	Wetlands area remaining in sq km	Wetlands Index where 100 equals the estimated original area covered by wetlands in Alberta (25,000 km^2)	Peatlands, area change per annum (million ha)	Peatlands index where maximum area or minimum loss (1961) is benchmark for best	Cost of loss of wetlands (millions, 1998$)
1961	17,651	49.72	0.0021	100	6,392.77
1962	17,551	49.44	0.0021	99.99	6,428.37
1963	17,452	49.16	0.0021	99.98	6,463.97
1964	17,352	48.88	0.0021	99.96	6,499.57
1965	17,253	48.60	0.0021	99.95	6,535.17
1966	17,154	48.32	0.0021	99.94	6,570.77
1967	17,054	48.04	0.0021	99.93	6,606.37
1968	16,955	47.76	0.0021	99.92	6,641.98
1969	16,855	47.48	0.0021	99.90	6,677.58
1970	16,756	47.20	0.0021	99.89	6,713.18
1971	16,657	46.92	0.0021	99.91	6,748.78
1972	16,557	46.64	0.0021	99.90	6,784.38
1973	16,458	46.36	0.0021	99.88	6,819.98
1974	16,358	46.08	0.0021	99.94	6,855.58
1975	16,259	45.80	0.0021	99.81	6,891.18
1976	16,160	45.52	0.0021	99.74	6,926.78
1977	16,060	45.24	0.0021	99.69	6,962.38
1978	15,961	44.96	0.0021	99.52	6,997.98
1979	15,861	44.68	0.0021	99.55	7,033.58
1980	15,762	44.40	0.0021	99.66	7,069.18
1981	15,663	44.12	0.0021	99.52	7,104.78
1982	15,563	43.84	0.0021	99.49	7,140.38
1983	15,464	43.56	0.0021	99.49	7,175.98
1984	15,364	43.28	0.0021	99.47	7,211.58
1985	15,265	43.00	0.0021	99.37	7,247.18
1986	15,166	42.72	0.0021	99.22	7,282.78
1987	15,066	42.44	0.0021	99.15	7,318.38
1988	14,967	42.16	0.0021	99.15	7,353.98
1989	14,867	41.88	0.0021	98.99	7,389.58
1990	14,768	41.60	0.0021	99.22	7,425.18
1991	14,669	41.32	0.0021	98.89	7,460.78
1992	14,569	41.04	0.0021	98.98	7,496.38
1993	14,470	40.76	0.0021	98.59	7,531.98
1994	14,370	40.48	0.0021	98.70	7,567.58
1995	14,271	40.20	0.0021	98.80	7,603.18
1996	14,200	40.00	0.0021	98.64	7,628.61
1997	14,150	39.86	0.0021	98.64	7,646.41
1998	14,101	39.72	0.0021	98.64	7,664.21
1999	14,051	39.58	0.0021	98.64	7,682.01

Appendix C. U.S. GPI Cost of Loss of Wetlands

This appendix outlines the methodology used to estimate the cost of the loss of wetlands in the U.S. GPI report *The Genuine Progress Indicator – 1998 Update* by Anielski and Rowe *(1999)*.[47] The handbook accompanies a series of Excel spreadsheets for each of the 26 parameters of the U.S. GPI. Thus, references to "columns" in the description below relate to the accompanying spreadsheets. The U.S. GPI estimates includes estimates of the cost of the loss of wetlands that provide guidance to the development of GPI accounts for Alberta and Canada.

Cost of Loss of Wetlands in the U.S. GPI

Wetlands contain some of the most productive habitat in the world. Yet the value of wetlands are not represented in economic accounts because the benefits – such as regulating and purifying water, and providing habitat for fish and waterfowl – are generally "public goods," for which there is no overt price. When a farmer drains and fills a marsh, the GDP rises by the increased output of the farm. However, the loss of services from the wetland goes uncounted. The GPI rectifies that by estimating the value of the services that are given up when wetlands acreage is converted to other purposes.

According to the latest U.S. Fish and Wildlife Study (1997) the United States is continuing to lose wetlands but the loss has slowed to a rate 60 percent below that experienced in the 1970s and 1980s according to a new U.S. Fish and Wildlife Service report released today. While wetland restoration and creation activities have contributed to the national wetland base**,** the study showed a net loss of 117,000 acres per year between 1985 and 1995, much of which occurred in highly productive freshwater forested wetlands. For the first time in the Nation's history, there are fewer than 50-million acres of freshwater forested wetlands in the conterminous United States.

"Wetlands are crucial to the health of our environment," said Jamie Rappaport Clark, Director of the Fish and Wildlife Service. "This study shows that our Nation's efforts to restore and protect wetlands are making a difference."

According to the study, the factors contributing to the marked decline in the loss rate include implementation of the Section 404 wetlands permitting program of the Clean Water Act; state and local wetland regulatory programs; increased public awareness and support for conservation; expansion of Federal, state, local, and private- sector restoration programs that have contributed 78,000 acres a year to the national wetlands base; enactment of Swampbuster measures in the Farm Bills since 1985; and a decline in the profitability of converting wetlands due to the tax reform of 1986.

The U.S. Fish and Wildlife Service's National Wetlands Inventory measures wetland loss, which occurs when a wetland ceases to be a wetland. A wetland gain occurs only when a non-wetland becomes a wetland. Those changes are measured and reported in terms of acres. Between the 1780s and 1980s, what eventually became the 48 contiguous United States lost 54 percent of the estimated original 221-million acres of wetlands – a loss amounting to about 60 acres an hour for 200 years.

Between the 1950s and 1970s, the Lower 48 States lost an estimated 458,000 acres of wetlands each year; from the 1970s to the 1980s, the annual loss amounted to about 290,000 acres. The report, "Status and Trends of Wetlands in the Conterminous United States," is required by Congress at 10-year intervals.

Wetlands catch and hold floodwaters and snow melt, recharge groundwater, and act as natural filters to cleanse water of impurities. While wetlands comprise only about 5 percent of the land area in the conterminous United States, they vary widely in location, size, and type. They include saltwater habitats, freshwater habitats, and upland land use.

Loss of wetlands due to agricultural activity has abated somewhat but was still 924,000 acres from 1985 to 1995 (around 92,000 acres per year. Losses due to agricultural activity accounted for 79 percent of the 1985 to 1995 total loss. Urban and other development accounted for the remaining 21 percent of the total loss recorded for the same period.

The loss of wetlands is estimated at 462,000 acres per year (458,000 in the Lower 48 States and roughly 4,000 in Alaska) through 1975; 294,000 acres per year (290,000 in the Lower 48 States) from 1976-1984, and; 121,000 acres per year (117,000 in the Lower 48 States) in subsequent years 1985-1995. 1996 and 1997 loss figures are extrapolated at the same rate of 121,000 acres per year that is a reasonable assumption based on contact with U. S. Fish and Wildlife Service officials. All figures are from the most recent U.S. Fish and Wildlife Service's National Inventory and from the report, "Status and Trends of Wetlands in the Conterminous United States." The next report will be prepared for Congress in 2000. The Alaska figures are based on an average annual figure using opening and closing stock estimates from U.S. Fish and Wildlife Services.

In terms of total acreage of wetlands, we estimated that a total of approximately 136-million acres of wetlands were filled in North America from the colonial period to 1950. Acreage declined from an original 395-million (including the contiguous lower 48 states and Alaska) in the 1780s to about 259-million acres in 1950 – a loss amounting to 60 acres an hour for 200 years, according to *Status and Trends of Wetlands in the Conterminous United States,* Fish and Wildlife Service (1997). U.S. Fish and Wildlife studies estimate that between the 1950s and 1970s, the Lower 48 States and Alaska lost an estimated 462,000 acres of wetlands (458,000 acres in the Lower 48) each year; from the 1970s to the 1980s, the annual loss amounted to about 294,000 acres (290,000 acres in the Lower 48). A recent report Status and Trends of Wetlands in the Conterminous United States by Fish and Wildlife found that the loss of wetlands has slowed to a rate of 60 percent below that experienced in the 1970s and 1980s for a net loss of 121,000 acres per year (117,000 acres in the Lower 48) between 1985 and 1995 (much of which occurred in highly productive freshwater forested wetlands of which there are now fewer than 50-million acres remaining in the conterminous United States).

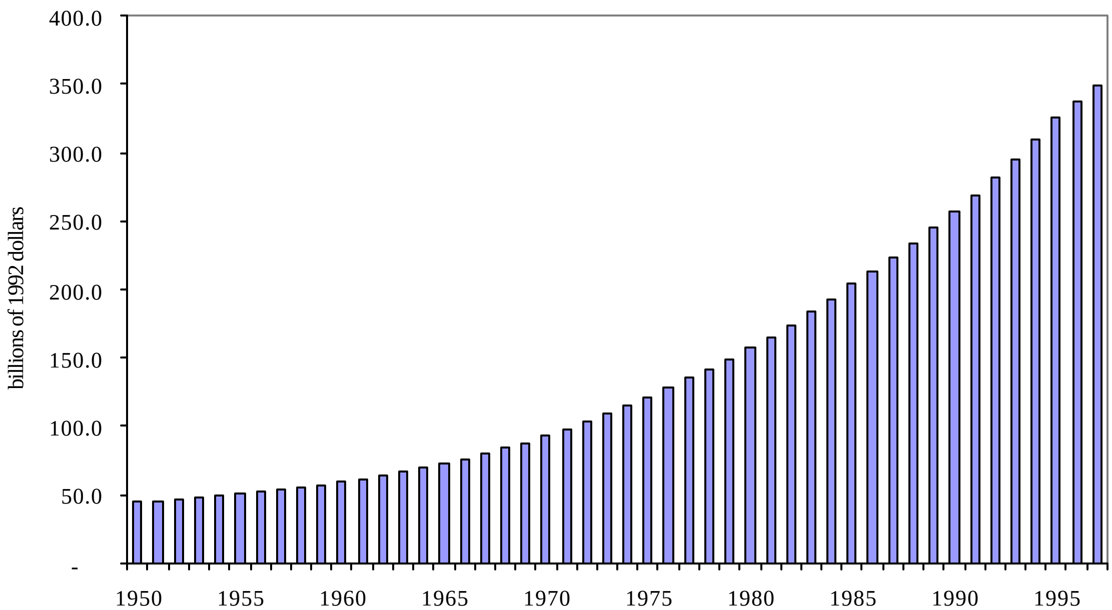
The value per acre (in 1992 dollars) of the flow of services from an acre of wetland is estimated at $1,973 per acre per year in 1950. This is lower than other estimates by Costanza, d'Arge, de Groot et al. (1997) who estimated the average global value of ecological services from global wetlands in 1997 ranging from $25,000/ac/yr for coastal wetlands to $48,000/ac/yr for swamps and floodplains in 1996. However, if we estimate the value of ecological services of the accumulated loss of wetlands up to 1997, our per acre per year value amounts to an estimated $19,543 (in 1992 dollars) which compares with the coastal wetlands figure of Costanza et al. (1997).[1] Compared with other studies, our estimate is a relatively conservative figure since calculations of the value of salt water wetlands have arrived at estimates 3 to 20 times as high. (See Lugo and Brinson, 1979). However, our figure exceeds another estimate by Gupta and Foster (1975) by about one-third the median.

[1] The figure of $19,543 per acre is derived as follows: $19,543 = $1,973 * 1.05 to the 47th power.

The loss of benefits from wetlands is a cumulative process. For example, if 462,000 acres of wetlands were filled or drained in each of two successive years, at the end of the second year the loss would equal the benefits from 924,000 acres of wetlands.

ECONOMIC COST OF LOSS OF WETLANDS

Figure 15



We begin the calculation with an initial value of $44.6-billion for the annual value of ecological services for all wetlands lost through 1949. Our figure of $44.6-billion for 1950 is based on the following calculations: an average value of $327.87 (chained 1992$) an acre of services from wetlands, multiplied by 136-million acres lost, yields $44.6-billion as a plausible estimate of the cumulative loss through 1949. The value of each of the initial tens of-millions of acres was lower than the marginal value of more recently filled acres. Starting in 1950, the value per acre of the flow of services from an acre of wetland was $1973 (in 1992 dollars) per acre per year. (That may seem like a sudden jump from $328, but that figure is an average of very low values for the first acres lost in the distant past with values close to $1973 in years through 1949.) In 1951 and following years, we assume that the value of wetland services rises by 5 percent per year, due to increasing scarcity. Thus the cost per lost acre in 1951 was $2072 ($1973 times 1.05), $2175 ($2072 times 1.05) in 1952, and so on. The acreage of wetlands to which this cost figure is applied also grew cumulatively since 1950: by 460,000 acres per year from 1950 to 1975, by 294,000 from 1976 to 1984 and by 121,000 from 1985 to the present.

The GPI account estimates the value of ecological services lost due to the accumulated loss of wetland in 1997 at roughly $350-billion, in 1992 dollars. The figure shows this progressive increase in the annual cost to the U.S. economy from the accumulated loss of wetlands since 1950.

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