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Climate Change and Long Point Bay: A Preliminary Analysis with Some Implications

Long Point Environmental Folio

Long Point Environmental Folio
Publication Series

Working Paper 2

Long Point Environmental Folio Publication Series
Managing Editors: J. Gordon Nelson and Patrick L. Lawrence

A study team at the Heritage Resources Centre is developing an Environmental Folio for the Long Point Biosphere to assist management agencies and local citizens in understanding the human and natural components of the ecosystem. The folio will consist of a series of maps and text that would outline current major management issues and areas of concern. A series of project publications is being prepared to accompany the folio. These reports will consist of supplementary information collected during the study. This project is supported by the Royal Canadian Geographic Society and the Social Sciences and Humanities Research Council of Canada.

CLIMATE CHANGE AND LONG POINT BAY: A PRELIMINARY ANALYSIS WITH SOME IMPLICATIONS

Tamara Staple

Long Point Environmental Folio
Publication Series

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Working Paper 2

Heritage Resources Centre
University of Waterloo

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HIGHLIGHTS

1. PURPOSE: is to give a preliminary analysis of the potential changes in climate under a 2XCO2 scenario and to explore some of the implications for the Long Point Bay area, especially the Inner Bay.

2. MOTIVATION: arises from the issue of global warming and other changes associated with increases in carbon dioxide (CO2) and other greenhouse gases resulting from atmospheric pollution, especially during the past century of growing industrial development internationally.

3. METHOD: Projecting the nature of a future climate for Long Point is very difficult. The best tool presently used in understanding the change associated with increases in greenhouse gases is a general circulation model (GCM), which provides climatic conditions given a CO2 concentration of 500 ppm within the atmosphere. However, uncertainties about the timing, magnitude and rates of change exist and therefore output from GCMs are not predictions of a future climate but rather are approximations of possible conditions. Output of mean monthly temperature and precipitation data from the Canadian Climate Centre (CCC) General Circulation Model (GCM) is added to the existing mean monthly temperature and precipitation regimes in order to explore the changes in climate for Long Point as CO2 concentrations within the atmosphere double. Data from the CCC GCM is fed into a Great Lakes hydrological model and the resulting output is compared with an International Joint Commission Basis-of-Comparison data set to derive changes in monthly mean Lake Erie water levels.

4. RESULTS: Long Point may experience a warmer mean temperature by 5.7^{o}C, a decrease in total precipitation of 6.3% to 857 mm, and a lowering of lake levels by 1.35 m. Although the extent of "open" water of the Inner Bay would be reduced, a channel to the Outer Bay would likely remain, thus providing continued access to Lake Erie. The smaller Inner Bay area may retain the diversity of submerged macrophyte species and wildlife species if the substrate remains relatively similar to present conditions and the vegetation migrates in step with the receding shoreline. However, the distribution of these species may alter as the remaining Bay could not support present populations. In addition, although the variety of recreational activities that the Bay could offer would remain, extensive and expensive alterations may be required to make camping and marina facilities operational under the new conditions. Finally, policies concerning water allocation, ownership of newly exposed lands, and monitoring of climate are needed if the region is to successfully adapt to changing environmental conditions. The formulation of these policies must involve local people and will be fraught with communication and other difficulties because of uncertainty not only about the magnitude and nature, but especially the timing or rate of changes.

5. SIGNIFICANT AREAS: The northeast, southwest and southern shorelines of the Inner Bay are all considered to be areas important to the sustainability of the wetland character of Long Point and most sensitive to changes in climate and lower water levels. The shallowness, diversity and productivity of submerged macrophytes characteristics of these areas will likely result in large changes occurring as water levels decrease. These areas should be the focus of planning activity if the wetland ecology of the Long Point area is to be sustained.

6. RESEARCH: More impact analyses are required which would cover such sectors as fisheries, terrestrial vegetation, and emergent macrophytes for the Long Point area. In addition, further investigations into potential areas of significance, including the Outer Bay, are needed in order to make informed and appropriate management and planning decisions.

GLOSSARY

Basis of Comparison (BOC) - a data set consisting of the average monthly mean Lake Erie water levels from 1900-1989 and are used to represent the existing water levels for comparison with other data sets such as GCM output.

Carbon dioxide (CO_2) - a trace gas in the atmosphere exhibiting properties which trap radiation near the earth's surface, thereby warming it. Over the past century, levels of CO_2 in the atmosphere have substantially increased due to human activities. It is thought that these rising levels could initiate a warming of the average global surface temperature.

Chlorofluorocarbons (CFCs) - organic molecules consisting of chlorine and fluorine bonded to carbon. Used as spray can propellants and coolants. Previously thought to be inert, but now known to destroy the ozone layer.

General Circulation Models (GCMs) - highly complex computer models used to estimate future large-scale climatic conditions given an increase in CO_2 levels in the atmosphere to 500 ppm.

Greenhouse Effect - mechanism that explains atmospheric heating caused by increasing carbon dioxide and other trace gases. Carbon dioxide is believed to act like the glass in a greenhouse, permitting visible light to penetrate but impeding the escape of infrared radiation or heat.

Lake Level Fluctuations - the rise and fall of water levels within a large body of water over a period of time.

Macrophytes - large, aquatic plants (eg. crowfoot or water lily), as opposed to phytoplankton or other small algae.

Methane (CH_4) - simplest of hydrocarbons, product of natural or artificial anaerobic decomposition. Like other greenhouse gases, it prevents radiation from escaping into the outer atmosphere.

Nitrogen oxides (NOx) - oxides formed during combustion by the oxidation of atmospheric nitrogen at high temperatures and is also considered a greenhouse gas.

Substrate - the surface to which an organism is attached or upon which it moves.

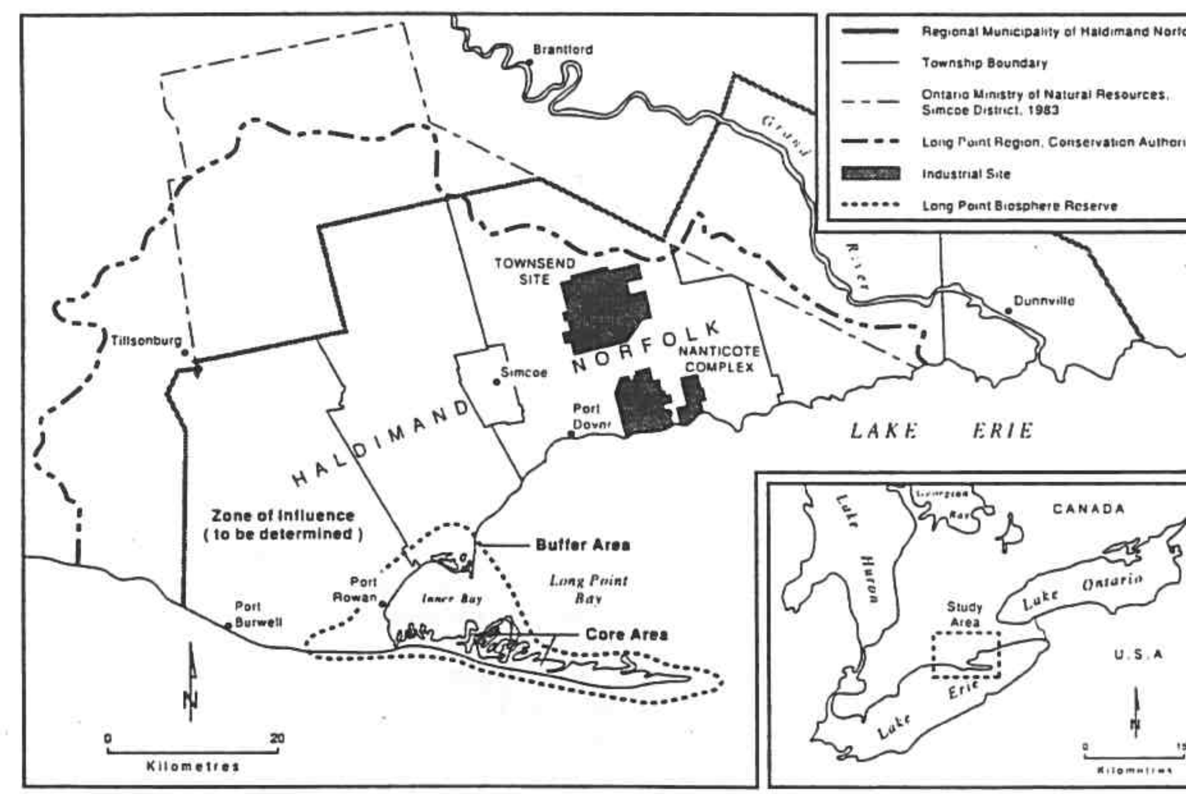
Vegetation succession - the progressive natural development of vegetation towards a climax, during which one community is gradually replaced by others.

CLIMATE CHANGE AND LONG POINT BAY: A PRELIMINARY ANALYSIS WITH SOME IMPLICATIONS

1.0 INTRODUCTION

The Long Point region, on the northern shore of Lake Erie, is one of the few relatively large, wild wetlands remaining in Ontario. Both physical and ecological processes have combined to create a unique, rich and diverse biological habitat which has merited international designation as an outstanding wetland or Ramsar site and a Biosphere Reserve. The physical and ecological processes at work in the Long Point region include shoreline erosion and deposition, geochemical cycling, seasonal and longer term lake level fluctuations, and vegetation succession and animal migrations. All these processes are dependent, to varying degrees, upon climatic factors. Any changes in the present climate could therefore have repercussions on the physical, ecological and socioeconomic patterns of the Long Point region and especially the marshes and waters of the Inner Bay (Figure 1).

Figure 1 Long Point Region and Study Area



Climatic History

The climate of Long Point has been constantly changing throughout geological history. Ancient climates of the area have fluctuated among warm, alternately wet and dry, semi-arid, and glacial climates (Phillips, 1989). During the Quaternary, which began almost two million years ago, four to eight major glaciers advanced over the Great Lakes region. As a result, the Long Point area was covered with thick glaciers at times and exposed to cooler climates and higher and lower lake level at others. While being significantly warmer than previous glacial times, the present interglacial climate or Holocene - which began 10,000 years ago - has also fluctuated between relatively warm and cool intervals. During the Hypsithermal of 7000-3500 years BP, the summers are estimated to have been 2 to $3^{o}C$ warmer than at present. During the Little Ice Age of 1300-1750 AD, temperatures are thought to have averaged annually 1.2oC below present levels (Phillips, 1989).

It is reasonable to assume that since the climate of Long Point has changed in the past, it will continue to do so in the future. Monitoring and assessment of climate should help to reduce the uncertainty associated with any future climatic change and in doing so, will be useful in the determination of management strategies for Long Point. This study is an assessment of possible changes in the Long Point climate and environment which could arise as a result of global warming and other changes associated with increases in carbon dioxide (CO_2) and other greenhouse gases resulting from atmospheric pollution, especially during the last century of growing industrial development internationally. In attempting to predict such changes, scientists have worked with predicted likely amounts of CO_2 and other greenhouse gases, and interpreted their effects on terrestrial and other climatic and environmental factors. This is because the slow rate of changes, the difficulties in developing correlations among CO_2 and other greenhouse gases, make this the only feasible approximation at this stage. It does, however, make it difficult to know the rate at which changes will approximate those predicted by $2XCO_2$ models.

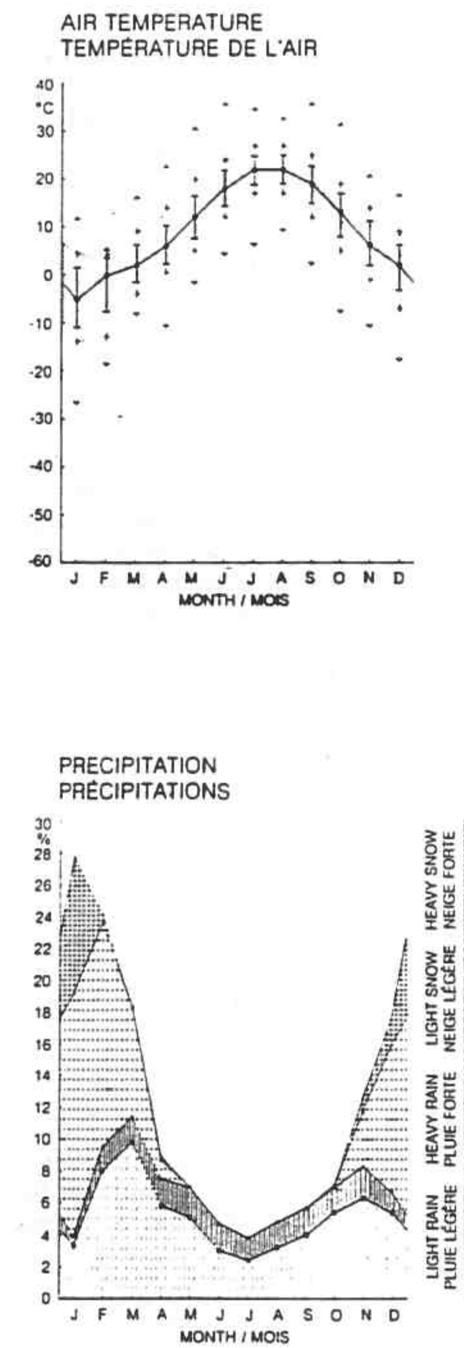
Rationale and Outline

The purpose of the study is to give a preliminary analysis of the potential changes in climate under a $2XCO_2$ scenario and to explore some of the implications for the Long Point Bay area. The report begins with a brief overview of the current climate for Long Point Inner Bay. This is followed by an examination of the climate change issue, focussing on the Greenhouse Effect, the relationship between increase greenhouse gases and warmer climate, and policy strategies. The third section investigates the potential climatic changes for the Long Point area given a doubling of CO_2 levels in the atmosphere. The final section explores the implications of the potential climatic change for water levels of the Inner Bay and vegetation, wildlife, recreation and policy issues of the Long Point area.

2.0 PRESENT CLIMATE OF LONG POINT BAY

The Great Lakes region experiences one of the mildest and most benign climates of any region in Canada (Figure 2) (Phillips, 1990). The modified continental climate has four distinct seasons: a cold, snowy winter; a cool, short spring; a moderately warm summer; and a cool fall (Eichenlaub, 1979).In addition to controls such as latitude, air masses and continentality, the moderating presence of the Great Lakes significantly influences the climate of this region, including the Long Point Inner Bay area. The lake effects result in the shoreline areas being cooler in summer and warmer in winter than areas further inland. Precipitation is evenly distributed throughout the year, with snowfall accounting for 33% of the total precipitation for the Great Lakes region (Phillips, 1990), but is not evenly distributed throughout the Basin. Due to prevailing winds, elevation and slope of the land, the Long Point area does not accumulate the same amount of winter precipitation as more northerly inland areas such as Barrie, Ontario.

Figure 2. Lake Erie Region Climate
(from Saulesleja, 1986)



Climate data as specific to Long Point as possible is needed to represent the current climate experienced in the Inner Bay of Long Point and provide a basis for estimating future climatic changes due to increases in CO^2. Due to the lack of a meterological station along the Inner Bay, data from the very tip of Long Point peninsula has been partly used to depict a climate thought to be most similar to that of the Inner Bay. While acknowledging that the lake effects and other climatic forces would be greater at the tip than in the Bay, the Long Point station would still be a better representation of the Inner Bay's climate than a station that was located further inland such as Simcoe, or further along the northern shoreline such as Port Dover.

Problems arose with the climatological data from the station at the tip of Long Point. The average monthly temperature and precipitation values from 1936-1985 excluded the months of December, January, February and March, and thus left an incomplete record (Environment Canada, 1990). Although year-round data has been collected mechanically at the station since 1985, the format of the data was unsuitable for the study. Thus, in order to do this initial indicative analysis, it was assumed that, despite its inland location, St. Williams would be most representative of the winter climate of the Bay as it is the closest station to the Inner Bay. Based upon these assumptions, the current monthly temperature and precipitation values of Long Point Bay for April to November were averaged from 1936-1985, and for December to March were averaged from 1951-1980 (Figure 3). The Long Point area experiences a large annual temperature range with July temperatures of 21.1^oC and January temperatures of approximately -5.7^oC. The 926 mm of precipitation is typically relatively evenly distributed throughout the year.

Just as the Great Lakes modify the climate of Long Point, the climate of the region also modifies the water levels of the Inner Bay. Temperature, precipitation, wind, evaporation, seiches and cloud cover, all are climatic factors which influence the water depths at any given time in the Bay. Figure 4 shows the present bathymetry of the Inner Bay (for explanation of map, see Pauls and Knapton, 1993). Even slight alterations to the current climatic regime could be translated into significant water fluctuations in the Inner Bay.

3.0 VARIABILITY AND CLIMATIC CHANGE

The Greenhouse Effect

The greenhouse effect is an undisputed natural process. Existing within the atmosphere are particular trace gases which absorb some of the outgoing infrared radiation emitted by the earth's surface, thereby effectively warming the lower atmosphere (Kellogg, 1990). Carbon dioxide (CO^2), methane (CH^4) and nitrous oxides (NOx), are gases which perform this function similar to that of a greenhouse (Figure 5). Without such an effect, the earth's surface temperature would be more than 30^oC cooler (McBoyle, 1990).

Over the past century, concentrations of natural greenhouse gases, especially $CO2$, in addition to human-made gases gases such as chloroflorocarbons (CFCs), emitted from refrigeration and aerosols, have all increased as a result of human activities and in doing so, each has contributed to greenhouse warming (IPCC, 1990; Nilsson and Pitt, 1991). Through the burning of fossil fuels, deforestation, agriculture practices and industrial processes, the concentrations of these gases are presently continuing to escalate (McKay and Hengeveld, 1990). Given the nature of the greenhouse process and increasing levels of greenhouse gases within the atmosphere, some repercussions on future climatic regimes are to be expected.

Figure 3 Existing Mean Monthly Temperature and Precipitation at Long Point

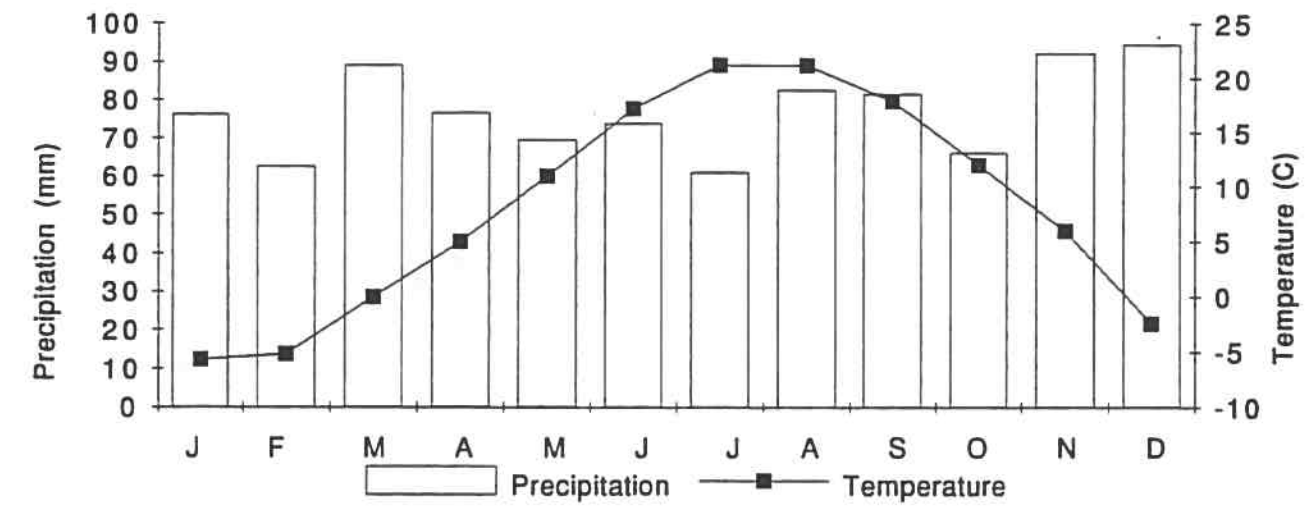


Figure 4 Water Depths in Long Point Inner Bay
(from Pauls and Knapton, 1993)

water depths in cm
marsh areas

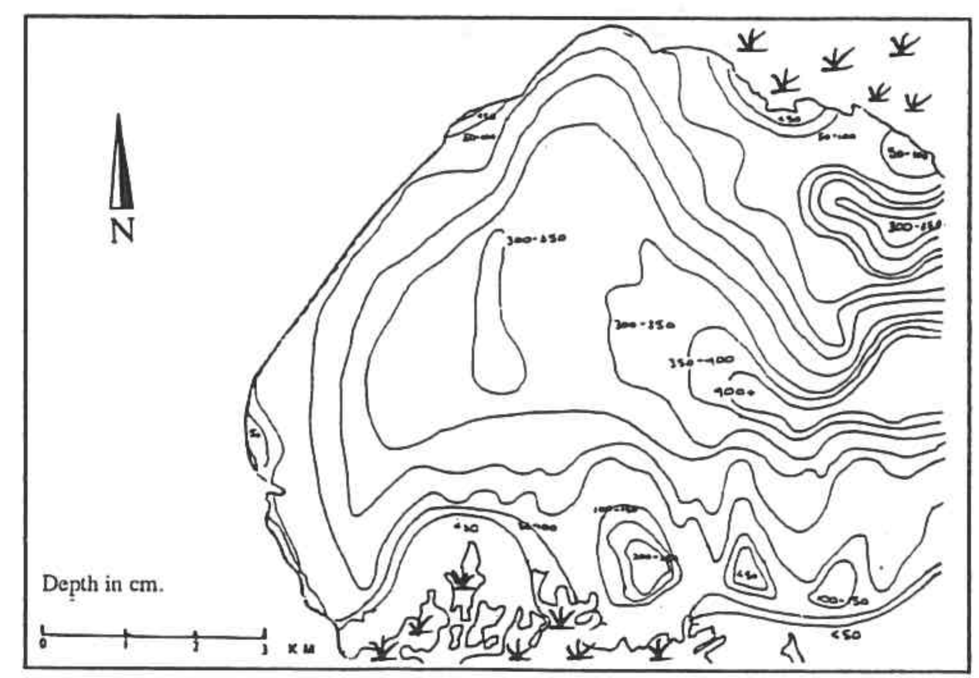
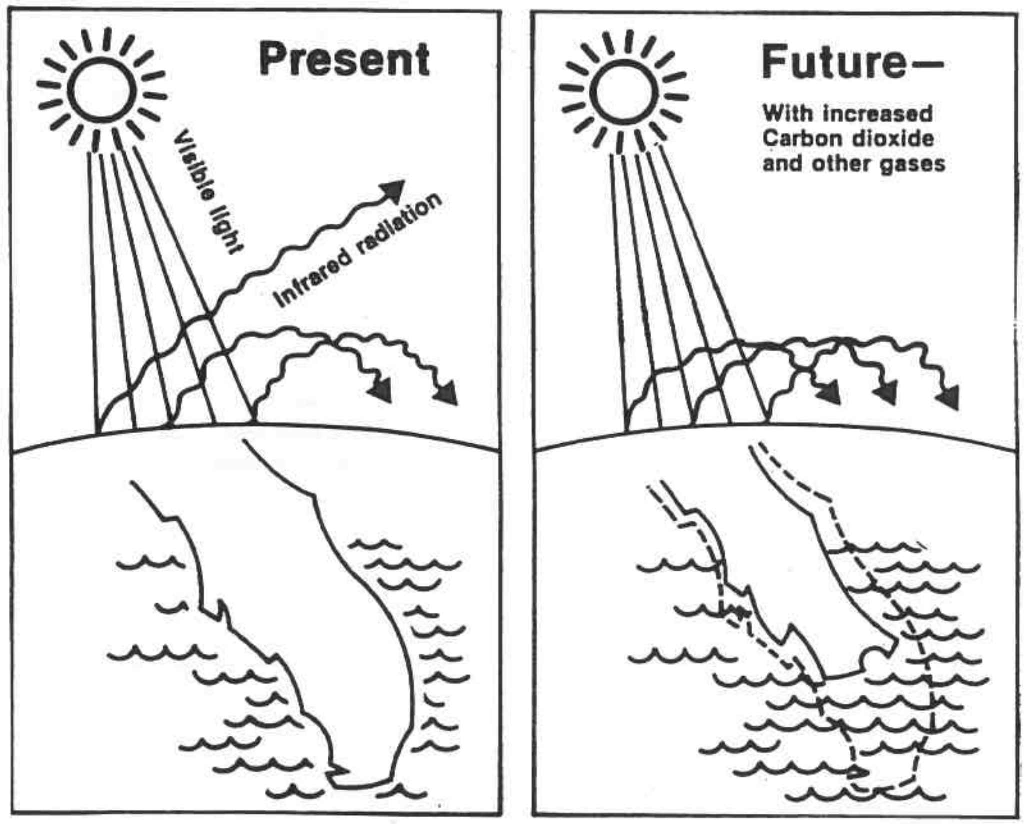


Figure 5 The Greenhouse Effect
(from McKay and Hengeveld, 1990)



Evidence of a Relationship Between Increased Greenhouse Gas Concentration and Warmer Climate

Although not conclusive, a growing body of evidence suggests that the continuing elevation of greenhouse gas levels may initiate and perpetuate global changes in climatic regimes. A two kilometer ice core retrieved from the glaciers at Vostok Station in Antarctica indicates a relationship between greenhouse gases and warmer climatic changes (Figure 6). The examination of trapped air bubbles in the 160,000 year record yields that CO^2 and methane (CH^4) concentrations in the ancient atmosphere varied in step not only with each other but also with the average local temperature (Schneider, 1990). Although CO^2 and CH^4 levels increased 25 percent and 100 percent respectively during the 10°C warmer interglacial periods, it remains unclear as to whether the greenhouse gas variations caused the climatic changes or vice- versa. Despite the lack of confirmation of a cause and effect relationship, this study does reveal the existence of a past association between increasing greenhouse gas concentrations and warmer global temperatures.

Investigations into the average global surface temperatures over the past century indirectly support a link between greenhouse gas levels and warmer changes in climate. Allowing for some variability in noise in the data, records of average global surface temperature have been interpreted to indicate an increase of 0.5°C over the past century (MacCracken, 1989; Sanderson, 1989). This warming coincides with the dramatic, and continuing magnification of greenhouse gas concentrations within the atmosphere over the same period (Figure 7).

The best tool presently used in understanding the change associated with an increase in greenhouse gases - in particular an increase CO^2 - is a general circulation model (GCM). These highly complex, three dimensional computerized models attempt to simulate current climates under a $1xCO^2$ scenario (250 ppm) and are then used to project what climatic changes may occur with a doubling of CO^2 (500 ppm). Among the models which could be used to estimate climate change and related effects in the Long Point area are: Canadian Climate Centre (CCC); Goddard Institute for Space Studies (GISS); Geophysical Fluid Dynamics Laboratory (GFDL); and Oregon State University (OSU) (Marie Sanderson, pers. comm.). Differences among models exist in terms of the estimated timing and magnitude of temperature and precipitation changes, especially on the regional scale. Yet in spite of the models' diversity, all GCMs indicate an increase in the average global surface temperature from 1.5 to 4.5°C under a $2xCO^2$ scenario (Schneider, 1989; Hengeveld, 1991). Moreover, scientists agree that the magnitude of annual climatic change will be greater with increasing latitude and during winter (Roots, 1989; McKay and Hengeveld, 1989). While GCMs neither <u>predict</u> future climates nor establish the cause and effect relationship among greenhouse gases and warmer temperatures, the scenarios or general pictures that they depict are nonetheless advantageous in diminishing the uncertainty associated with the issue of global climatic change by providing at least a first approximation of possible change as a basis for further monitoring and planning.

Policy Responses

Given the nature of the climatic change issue and the tremendous implications of a significant, rapid rise in average surface temperature, two policy strategies - limitation and adaptation - are currently used to address this concern (Smit, 1992).

Limitation strategies focus on the curtailing of greenhouse gas emissions through legislation prohibiting the use of CFCs and restricting CO^2 emissions, and in doing so, may help retard the warming process. However, due to high levels of greenhouse gases already in the atmosphere and the time lags that are already built into the system, society has, in all likelihood, committed itself to climatic change. In this light, policy responses which reflect only limitations on future greenhouse gas emissions are insufficient to deal adequately with the implications of an already changing climate.

Figure 6 Gases Contributing to Greenhouse Warming
(from McKay and Hengeveld, 1990)

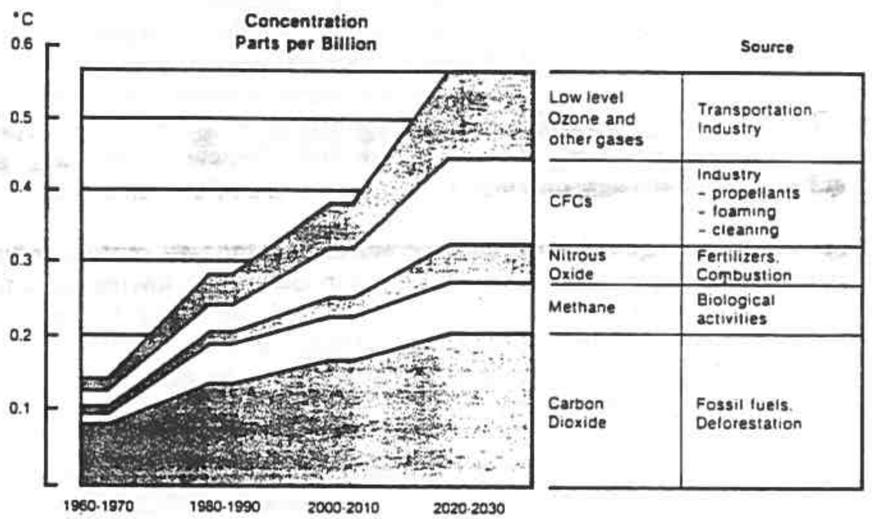
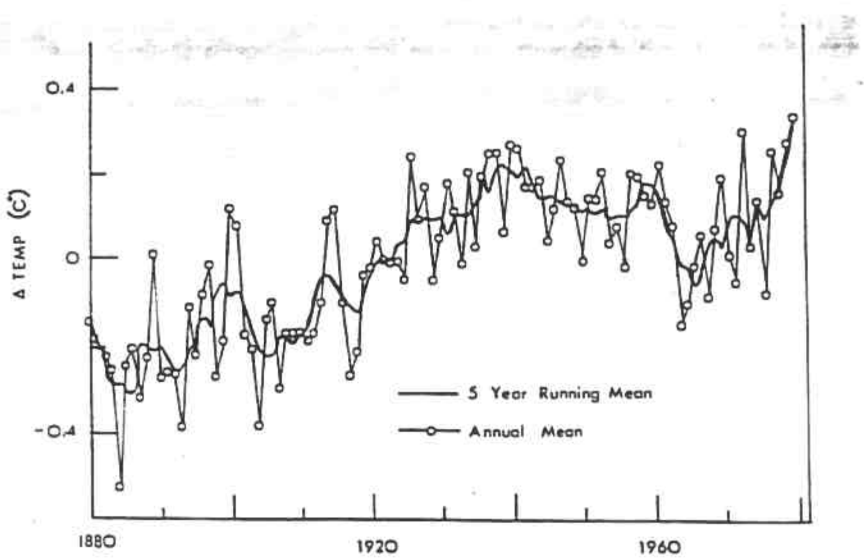


Figure 7 World Temperatures, 1880-1980
(from Sanderson, 1988)



Adaptation is a complementary policy, representing things that which can be done in the meantime to minimize environmental degradation while limitation initiatives are negotiated and implemented (Smit, 1992). Adaption strategies acknowledge the variability associated with climatic systems and as a result, estimate the impacts of possible future climates as a basis for evaluating the severity of the climate problem (Smit, 1992). These strategies attempt to address the implications of a changing climate on biophysical, socioeconomic and political systems, thereby reducing uncertainty so that appropriate policy decisions can be made. In the Great Lakes region, adaptive investigations have focused on such sectors as power generation (Cohen, 1987; Sanderson, 1987; Hartmann, 1990), navigation (Sanderson, 1987; Marchand et al, 1988; Hartmann, 1990), fisheries (Magnuson, 1989; Hartmann, 1990) and tourism and recreation (Cohen, 1987; Wall, 1988; Hartmann, 1990).

4.0 ESTIMATING POTENTIAL CLIMATIC CHANGES FOR LONG POINT BAY

Methodology

The output from the Canadian Climate Centre (CCC) GCM was used to determine the potential changes in climate for the Long Point Inner Bay. The CCC GCM has higher spatial resolution than other GCMs, such as GISS and GFDL which were tried in an earlier version of this paper. The CCC GCM therefore gives more than twice the information coverage and allows a much more detailed representation of local climatic processes (Hengeveld, 1991). The high spatial resolution and the fact that it is the most up-to-date GCM (Grace Koshida, pers. comm.), were two critical reasons why the CCC GCM was chosen for this study and other GCMs such as Oregon State University (OSU), Goddard Institute for Space Studies (GISS), and Geophysical Fluid Dynamics Laboratory (GFDL) were omitted.

The changes in climate in Long Point Inner Bay were estimated by adding the expected monthly changes in temperature and precipitation - as derived from the CCC GCM - to the current averaged monthly temperature and precipitation values (Table 1). In addition, changes to Lake Erie monthly water levels were derived by feeding $2xCO^{2}$ climate scenario data from the CCC GCM into a Great Lakes hydrological model. The estimated mean monthly lake levels were then compared with a Basis-of-Comparison (BOC) data set (IJC, 1993), which consisted of Lake Erie water levels averaged monthly from 1900-1989 (Grace Koshida, pers. comm.) (Table 2). The current water level of Lake Erie, represented by the average of the mean monthly water levels experienced from 1900-1989, was compared to the mean water level estimated from the CCC GCM in order to determine the change in water levels expected for Lake Erie.

Temperature and Precipitation Changes

As the changes in climate for Long Point are derived from the data of only one meterological station and from a human-made model with numerous limitations and assumptions, the reader is reminded that the following alteration in temperature and precipitation values from an increase in CO^{2}, is **not** a prediction of a future climate but rather is a possible scenario of what Long Point could experience at some point in the future. The scenario is produced largely to provide a way of communicating with concerned planners, politicans and citizens about what currently are probably only vague ideas about global or climate change for their area of interest.

Under the CCC GCM $2xCO^{2}$ scenario (Figure 8), substantial changes in both temperature and precipitation regimes are likely to occur for Long Point Inner Bay. Winter and spring temperatures are expected to warm by as much as $10.5^{o}C$, while summer and fall temperatures are likely to only increase slightly, possibly as little as $2.1^{o}C$. The annual precipitation regime is expected to decrease by 6.3% to 857 mm. Moderate increases may occur during winter; however, immense reductions in precipitation, up to 35%, can be expected from August to December. Such changes in temperature and precipitation regimes would have significant effects on the character of Long Point Inner Bay (Figure 9).

TABLE 1: EXISTING AND EXPECTED LONG POINT REGION CLIMATE USING CCC GCM OUTPUT

	CURRENT CLIMATE		CCC GCM OUTPUT (change)		2 X CO2 CLIMATE	
MONTH	PREC (mm)	TEMP (C)	PREC (%)	TEMP (C)	PREC (mm)	TEMP (C)
January	76.1	-5.7	2	10	77.62	4.3
February	62.6	-5.2	10	10.5	68.86	5.3
March	89.2	0	2	9	90.98	9
April	76.7	5	7.5	7	82.45	12
May	69.5	11	2.5	5.1	71.23	16.5
June	73.9	17.2	-5	4.6	70.2	21.8
July	60.9	21.2	19	4.6	72.47	25.8
August	82.7	21.2	-18	4.8	67.81	26
September	81.6	17.9	-28	4.3	58.75	22.2
October	66.1	12	-23	3.6	50.9	15.6
November	92.2	6	-35	2.1	59.93	8.1
December	94.4	-2.5	-9	2.5	85.9	0

Table 2: Changes in Mean Monthly Lake Erie Water Levels using CCC GCM output

Month	Present Conditions (m)	2 x CO2 Conditions (m)	Amount of Change (m)
January	172.85	171.49	-1.36
February	172.85	171.55	-1.30
March	172.94	171.64	-1.30
April	173.09	171.73	-1.36
May	173.15	171.80	-1.35
June	173.17	171.82	-1.35
July	173.15	171.82	-1.33
August	173.08	171.76	-1.32
September	172.99	171.65	-1.34
October	172.90	171.53	-1.37
November	172.83	171.44	-1.39
December	172.83	171.43	-1.40

Figure 8 Estimated Changes in Mean Monthly Temperature and Precipitation Values at Long Point

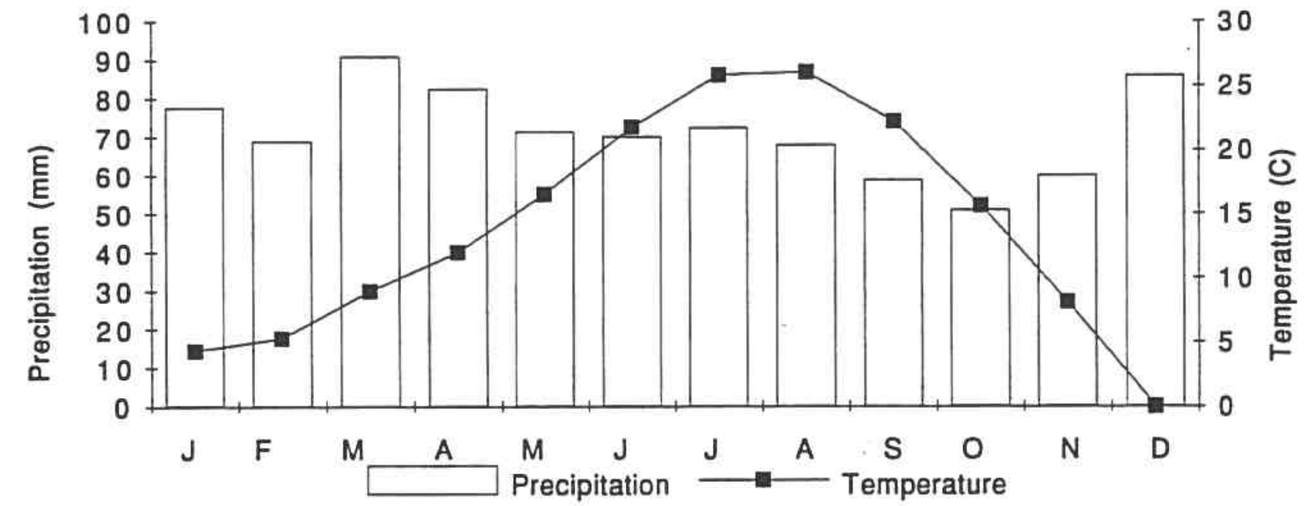
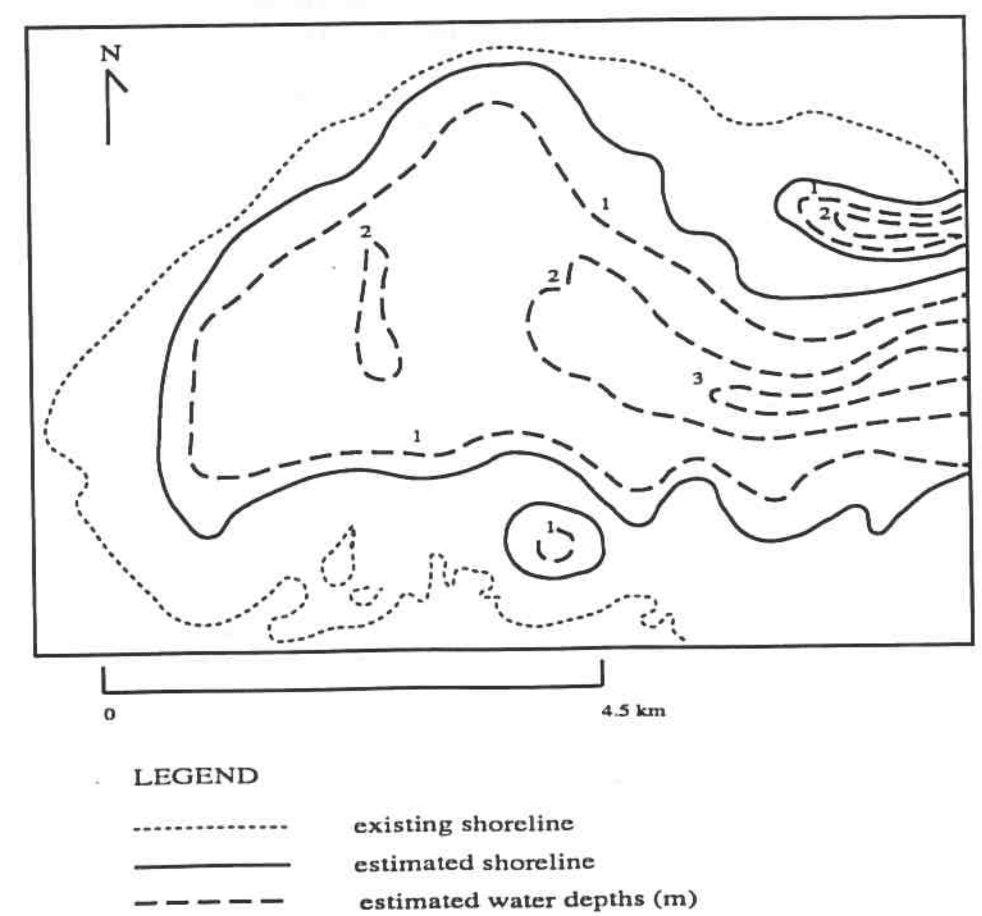


Figure 9 Changes in Shoreline Position and Water Depths of the Inner Bay



Lake Level Changes

Changes in temperature and precipitation regimes derived from the CCC GCM would affect the water levels of the Inner Bay. High summer temperatures and increased evaporation rates coupled with significant decreases in summer precipitation, could be expected to reduce runoff from the land, and thus, lower water levels. Lake Erie's water levels are expected to drop an average of 1.35 m (Table 2). With such a marked decrease in water levels, the nature of the Inner Bay may be altered (Figure 9). Remaining "open" water would be concentrated at the northern and northwestern portions of the Bay, with new land exposed in the shallower southwestern and northeastern portions. However, a channel likely would still connect the Inner Bay to the Outer Bay and hence, provide continued access to Lake Erie.

5.0 IMPLICATIONS OF POTENTIAL CLIMATIC CHANGE AND LOWER WATER LEVELS FOR LONG POINT INNER BAY

Wetland Ecology

The decrease water levels associated with warmer and drier conditions will likely have significant effects on the wetland environment of a large portion of the present Long Point area. Naturally confined marshes such as those at Long Point can be expected to revert to marsh meadow, succeeding to dryland conditions as the water table decreases (Wall, 1988). Protection provided by the sand spit would prevent the marsh from moving lakeward and vegetation likely would shift from species and communities favouring a water-loving to those favouring a more moderate medium. In doing so, vegetation will be altered dramatically as species intolerant of drying are replaced by hardier species from buried seeds and other sources. The diversity of the wetland ecosystem could decline as the flora of the terrestrial environment gradually dominate the Point (Wall, 1988).

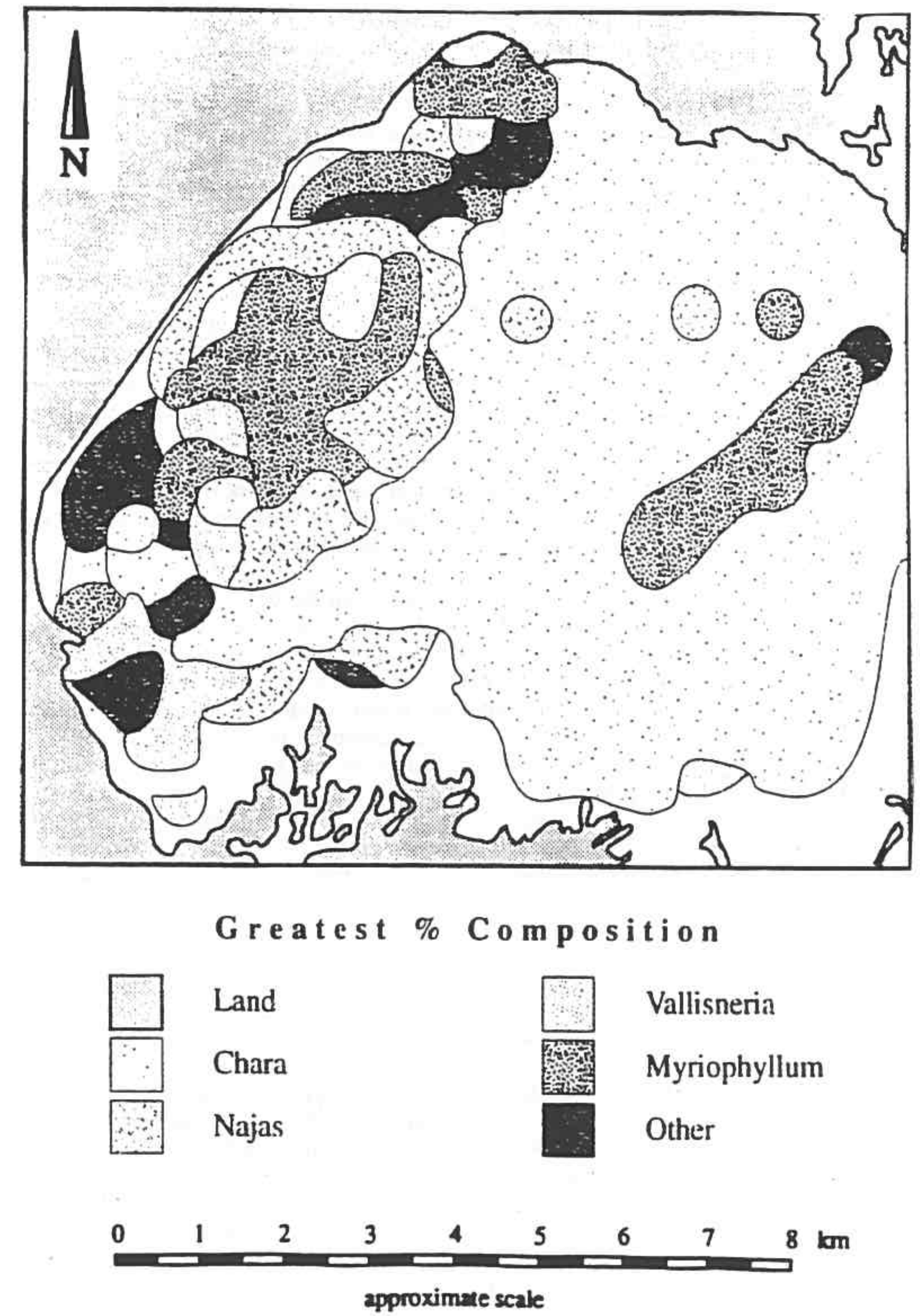
Extrapolating from the projected shoreline shown in Figure 9, the areal reduction of the marshlands in the Inner Bay can be deduced after a 1.35 m decrease lake water levels. The present marshes of the Inner Bay would most likely be replaced by terrestrial vegetation under the expected warmer and drier conditions. Lower water levels would be expected to combine with the relatively sandy substrate to lower retention of the moisture required for wetland vegetation growth. The substrate of the Inner Bay may change somewhat as climatic and erosion, deposition and other conditions change due to reduced runoff and less turbulence. However, if the substrate distribution were to remain relatively similar to present conditions, the "new" Inner Bay would consist primarily of sandy loam and sand with some muds concentrated in the western portion.

Based upon the submerged macrophyte research of Pauls and Knapton (1993) (Figure 10), the Inner Bay would support primarily *Chara* (musk grass) in the larger sandy loam sections with *Myriophyllum* (Eurasian milfoil) possibly still occurring in the deeper portions of this area. As most macrophyte diversity exists in muddy substrate areas, the northwestern portion (although significantly decreased), would most likely continue to support *Najas*, *Vallisneria* (wild celery), *Ceratophyllum* (coontail), and *Potamamogeton* (pondweed). The changes to the emergent macrophyte areas (marshes) have yet to be determined as work in this area was being conducted at the time of writing. Hence, it would seem that under a 2XCO^2 scenario, the Inner Bay would most likely have increased terrestrial vegetation along its southern and northwestern portion. The diversity of the submerged wetland vegetation species would likely remain, but the distribution would be altered.

Wildlife

The animal species of Long Point Bay are closely associated with the wetland environment and climate. The marshes of the Inner Bay provide suitable habitat for thousands of migrating birds and waterfowl. The long grasses of the marsh protect the waterfowl against predation while the abundant

Figure 10 Submerged Macrophyte Distribution in Long Point Inner Bay (from Pauls and Knapton, 1993)



shorelines provide staging and nesting habitats. In addition, the shallow marsh and bay areas support spawning and nursery grounds for a variety of fish species. Whillans (1979) and Mahon (1979) both comment on fish diversity, species population structure, and fish dependency on the marsh environment.

With the onset of any climatic change, the existing biological character of the Long Point Bay area may be altered. Many of the marshes of the Inner Bay would drastically decrease in area or even vanish as water levels fall. As the wetland vegetation migrates out into the Bay, so will its associated wildlife such as waterfowl, amphibians and fish. Although, as mentioned earlier, the areal extent of the Bay's marshes have yet to be estimated, it is plausible that if the diversity of submerged vegetation remained, the diversity of waterfowl and fish species - which depend on the vegetation for food and protection - would also remain. However, due to the reduction in "open" water under a $2XCO^2$ scenario, the populations of waterfowl, fish and amphibian species that the Inner Bay could support, becomes a serious ecological concern. The population per species that the Inner Bay could support may decrease than the diversity of the wildlife.

Recreation

Presently, the Long Point Bay region supports a variety of recreational activities. The abundant variety of waterfowl and fish species of the marsh area provide sport for hunter and sport fisherman alike. Some of the fastest growing recreational activities in the Inner Bay include boating, camping, and cottaging, in addition to bird watching and other less resource consumptive activities. Currently, approximately 2800 boatslips exist in the area's marinas and cottages (Patrick Lawrence, pers. comm.). Between Turkey Point and Long Point Provincial Parks, there are 13 marina facilities as well as 20 available boat launches. Moreover, 1500 trailer and campsites exist in the region within a two mile radius of shore. Numerous marina facilities and an expansion of Long Point Provincial Park have been recently proposed as tourism is becoming a major economic factor in the region.

A reduction in water levels would have significant impacts on the tourist and recreational activities of Long Point and on the economy of the region. As the marshlands are likely to decrease in extent, pressure may increase to preserve the remaining habitat and its inhabitants, which would result in the loss of waterfowl hunting and sport fishing opportunities within the region. Most of the present marina facilities would not function under the expected water level reductions, especially along the southwestern and northeastern shorelines (Figure 11). Campsite facilities of the Inner Bay could fall into disuse as the lakeshore receded and was displaced by grass, shrubs and/or forest vegetation. Thousands of dollars may have to be spent restoring these recreational facilities to operative locations and conditions. However, other economic factors being equal, the expected warmer, drier, longer summer in conjunction with newly exposed beaches, could continue to attract thousands of visitors to the Provincial Parks, Conservation Areas, private beaches and cottages of the Inner Bay each year.

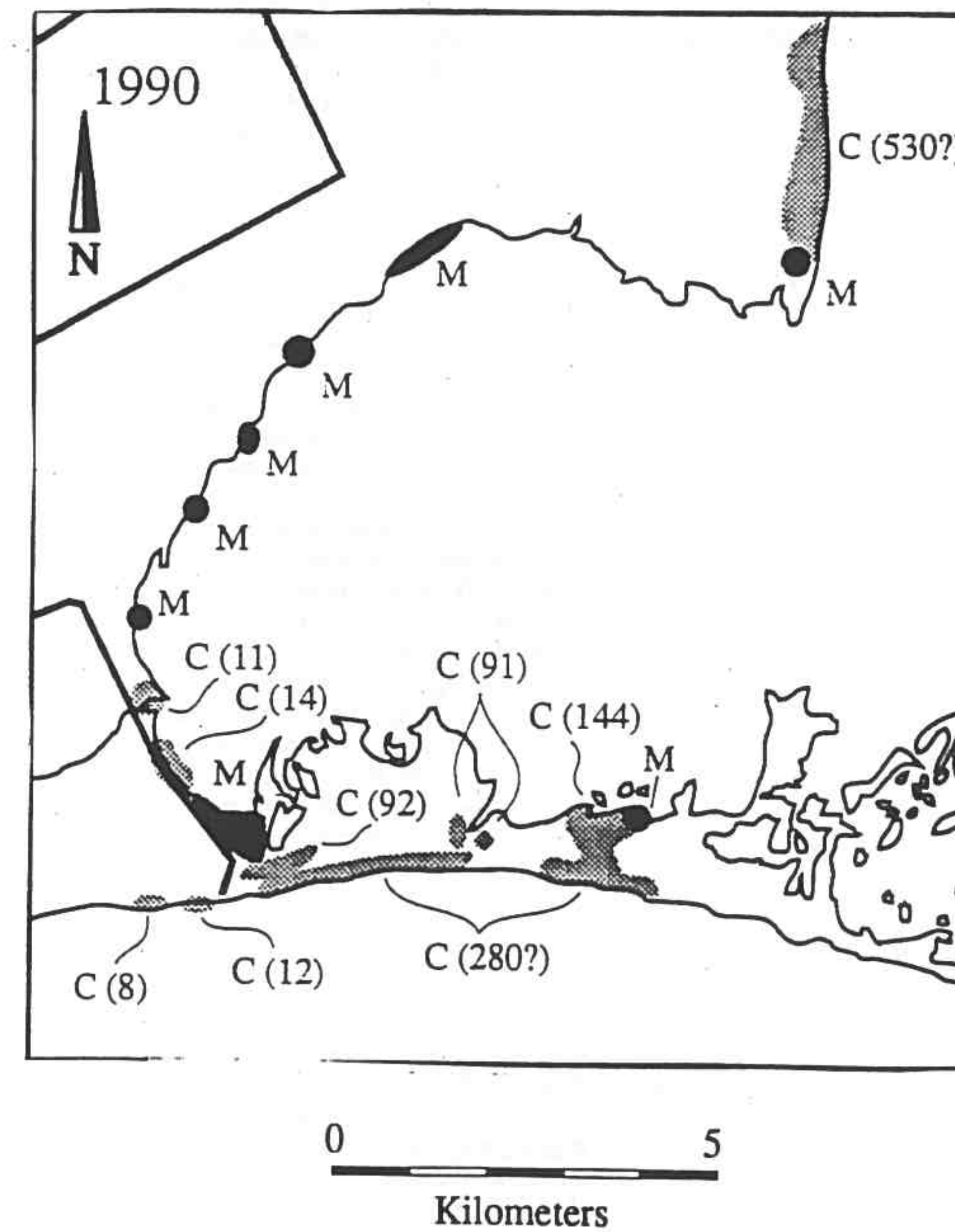
Policy Issues

With the threat of a future climatic change, policies which would enable the Great Lakes region - and Long Point - to remain adaptive and flexible in the face of uncertainty, should be initiated immediately. Policies which promote and support resiliency of the vegetation, wildlife and other aspects of the environment would allow for dealing with the unexpected and therefore, aid in the sustainability of the area (Holling, 1978). Resiliency can be promoted and supported by policies which favour diversity of plants and animals, protection of ecological processes essential to the health of the wetland environment, such as fluctuating water levels, and productivity by control of nitrates and other sources of pollution and biological change.

Despite the time and other uncertainties associated with the climate change issue, policies concerning water supply and quality, land use and economic development need to be considered now if the Great Lakes Basin is to adapt successfully expected changes. Although most policy makers are hesitant to

Figure 11 Cottage and Marina Facilities along Long Point Inner Bay

M = Marinas
C = Cottages



make decisions in which the benefits, if any, may initially be felt decades into the future, waiting for definitive proof of the nature and rate of change could result in costly planning errors. As Donahue (1992) states "scientific certainty is not an absolute precondition to formulating policy responses to the climate change issue. In the final analysis, it is more comforting to be well prepared for a crisis that never materializes than to be unprepared for one that does".

Basin-wide policy strategies for the Great Lakes have been discussed by Mortsch and Burton (1992), Donahue (1992; 1993), as well as at numerous Canada-US workshops (1989; 1992). Considerable agreement exists that policies regarding water resources, natural ecosystems, recreation, agriculture, transportation and energy, should be proactive and anticipatory rather than reactive. In addition, more sophisticated impact analyses and continued climatic monitoring have been cited as two useful exercises which would enable Canada and the United States to make informed policy decisions (Canada-US Workshop, 1989). On a smaller scale, several policy issues arise concerning how the Long Point area can adapt to warmer temperatures, decreased precipitation and lowered water levels in the Inner Bay. These issues focus on water resources, ownership of the newly exposed lands, and the sustainable management of the Long Point area through the Biosphere Reserve.

The projected changes in climate would most likely result in an increase in the demand for water in the Long Point Bay region at a time when there would be a decrease in the availability and quality of water in the Inner Bay. As the agricultural, industrial and residential sectors of the region all require varying amounts of water, pressures on the Inner Bay would mount as the competition for water escalated. Hence, policy and planning decisions involving water allocation and quality for the Inner Bay should anticipate the possibility of a significant reduction in levels from the Bay. Ideally, planning would address other means by which the residents of the area could obtain water, thereby the pressure on the remaining water needed by migrating waterfowl and other wildlife.

With the expected reductions in water levels for the Inner Bay, policy questions concerning ownership of newly exposed lands arise. Should the lands be made available for purchase by the private sector or should the lands be managed by the public sector? Those who operate marina or camping facilities may want the opportunity to expand their operations to the new shoreline and thus, would welcome the option to purchase the newly exposed lands. However, from an ecological viewpoint, having the exposed lands become property of the public sector (eg. Conservation Area, Canadian Wildlife Service) would protect the remaining pockets of vital wetland vegetation and wildlife in the Bay. Any policy direction for ownership of the newly exposed Inner Bay lands could depend upon the long term objectives and work of the Long Point Biosphere Reserve. As the objectives include managing for the sustainability of the ecosystems characteristic of the Long Point area, land use policies could favour ownership of exposed lands by agencies which would be committed to the sustainability of the wetland ecosystem.

Finally, a major step in enabling the Long Point region to adapt to climatic change would be continued monitoring of climatic parameters. The Long Point area seems, with its shallow waters, wetlands, and diverse habitats, to be an area of relatively high susceptability to global warming effects and to loss of significant environmental and ecosystem values. Establishing more meterological stations along the western shore of the Inner Bay would give a better representation of the climate experienced in this area and the continuous monitoring would detect the changes in climate brought about by natural or human-caused events. Results from this monitoring could then be used to make more informed, appropriate and sustainable policy and management decisions for the Long Point region. A policy implementing continued climatic monitoring is therefore urgently needed. Not only would it acknowledge the variability of climate at Long Point but it would also set the region on the path of adaptation rather than reaction to potential environmental changes.

6.0 CONCLUSION

As increases in CO^2 may result in warmer temperatures, decreased precipitation and lower water levels for the Long Point region, the sustainability of its wetland ecosystems will be dependent upon appropriate planning and management decisions. Identifying areas of significance would assist planners in prioritizing activities and in determining further research needs. Such areas would be important to the sustainability of the region and would most likely experience the greatest change upon being exposed to constraints such as climatic change and lower lake levels. Using the criteria of diversity (biodiversity, geodiversity, cultural), essential processes, productivity, and equity, the northeast, the southwest and the southern shores of the Inner Bay were all judged to be areas of significance. Since these shoreline areas are very shallow and have the greatest submerged macrophyte diversity and/or productivity, they would probably be the most sensitive to the expected reductions in water levels accompanying climatic change and therefore could experience the greatest ecological and hydrological changes, especially if the wetland vegetation does not migrate in step with the receding shoreline.

Another potential area of significance to be further explored would be the Outer Bay area. As decreasing water levels could eventually isolate the Inner Bay from Lake Erie, the quality of the remaining stagnant water would decline in reference to oxygen, transparency and pollutants. As a result of climatic change, the importance of the Outer Bay as a source for domestic and industrial consumption, and recreation could increase and be accompanied by substantial physical changes to the area. Thus, by identifying areas which would be most sensitive to a changing climate and lower water levels, planners and policy makers can use the information to develop strategies which would encourage the sustainability of the Long Point region.

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