

Integration of Climate Change Into Watershed Management

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PURPOSE

This paper seeks to provide an historical overview of Watershed Management; an introduction on how climate change will impact watershed management; will make several observations and recommendations about flood control, erosion control, stormwater management, fisheries management, and terrestrial management; and will address the types of adaptation strategies necessary for successful Watershed Management in a future changing climate.

BACKGROUND

Watershed Management, the practice of managing natural resources on the basis of a physio-graphic Watershed boundary, began in Ontario with the establishment of Conservation Authorities following World War II. Since then, its definition has expanded: first from a focus on flood control and erosion to one which includes broader terrestrial and aquatic environments, and more recently to include social issues related to the use of the natural environment, making watershed management one of the most inclusive ecosystem-based management frameworks, developed to date. Now, it must expand again to address Climate Change, and must do so with respect to natural science, mitigation, and adaptation, terms which will be explained in more detail below.

Managing on an ecosystem basis involves the recognition that all components of the natural hydrologic system are interconnected to the extent that changes to one component often are reflected in significant impacts or alterations to the other ecological components. An example of this fact is quite apparent when we look at the changes which have been occurring within watersheds with increased urbanization.

In the 1970's, it was recognized that urban land forms removed permeable areas and replaced them with impermeable surfaces, thus generating a higher volume of water. This increase in volume was being characterized as increased surface runoff, less evapotranspiration, less surface depression storage and therefore less infiltration. The overall consequences of this land form change has been increased flooding and erosion along receiving streams.

Early attempts to deal with the increased volume of water within our rivers and streams was centred around stormwater management by shaving peak flows to try and match post development peak flows to pre-development levels. While this practice is now commonplace, it falls short of dealing with all the impacts of urbanization. Higher flow volumes and peaks create erosion along the watercourses, resulting in significant impacts to infrastructure and to the form and function of the aquatic habitats.

In addition, water quality has been degraded to the point that many streams now support a significantly different, or much reduced fishery. The change in the aquatic environments has now begun to affect both the flora and fauna that exists within our valley systems. While new initiatives have been introduced that attempt to reduce the impacts on the natural systems through development, changes continue to occur as a consequence of past and current actions. For instance, recent work by Dr. Craig McCrea suggests that, upon completion of a watershed becoming urban, the impacted watercourse may require between 35-200 years before adjusting to its revised flow regime depending on flow channel soil conditions.

Current initiatives and strategies of Watershed Management hinge on working in concert with the dynamic aspects of the natural environment and its features. An example of this would include managing the watercourses based upon their valley and stream corridors to allow for the natural process of meandering streams as a component of a larger conveyance feature. This management strategy allows

for the evolution of the system through sediment transport issues such as erosion and deposition along a reach of stream. The development of strategies related to natural heritage features on a watershed also allow for an integration of flexibility and evolution within the system. As such, the concept of management on a watershed is based to some degree on the ability to manage and plan within the system, while allowing natural processes and changes to continue to take place. The watershed and its current management objectives, therefore, inherently allow for some degree of adaptation related to the potential impacts of climate change.

Traditional management of watersheds from an aquatic perspective has centred around mitigating impacts related to land use change for the portions of the hydrologic cycle where precipitation moves over the landform to the receiving watercourses. Climate change will bring changes to the atmospheric components of the cycle. Changes in evaporation rates, severity of storms, increased temperatures and droughts created through climate changes may result in significant alterations within the natural ecosystem of a watershed.

Climate change is a consequence of an increase in greenhouse gases (GHG) such as carbon dioxide within our atmosphere and from changes in landform. The burning of fossil fuels and the continued loss of terrestrial resources worldwide have led to these changes and we are only now beginning to understand some of the future consequences of these actions. While this issue has gained an international profile in recent years, our ability to stop or reverse the impacts are somewhat limited due to the residence time of these gases within our atmosphere.

Current initiatives to deal with climate change are focused on reducing our loadings of greenhouse gases into the atmosphere. Due to global economic and technical capabilities, these loadings may not

be eliminated in the foreseeable future. In addition, carbon dioxide has a residency time of near 90 years aggravating the existing problem. We can expect that GHGs will continue to increase, reaching levels over the next 50-70 years that are double those of pre-industrial times. As a result, the climate of the Great Lakes Basin is expected to change dramatically within this period. Climate change may provide some advantages and opportunities, as long as measures are taken to realize the potential benefits. The Toronto Niagara region's success in responding to these challenges will hinge on the ability and willingness to effectively incorporate climate impacts and adaptation into the planning processes. Given the size of this region's population and industrial base, our actions will also be crucial to Canada's success in achieving its greenhouse gas reduction targets under the Kyoto Protocol.

The various climate models are in general agreement that annual average air temperatures in southern Ontario may rise by 2 to 5°C by the end of the century (Smith et al, 1998). This warming is expected to drive possible decreases in soil moisture, surface water runoff, and lead to declines in water levels on the lower- and mid- Great Lakes. Changes in atmospheric circulation patterns and storm tracks may also affect wind patterns, the frequency of storm surges, erosion, and the intensity of storm rainfalls. Shipping activity, hydroelectricity production, and the stability of aquatic and near shore ecosystems may be affected by lower lake levels and warmer water temperatures. In addition, the projected decline in water supply, coupled with ongoing population expansion and resulting increases in water consumption, may lead to greater competition for water. Urban infrastructures may sustain increasing damage from more intense storm rainfalls and other weather extremes, while human health may be affected directly by increased heat stress and indirectly by more amenable climatic conditions for air pollution episodes and for vector-borne diseases such as Lyme disease and malaria. Longer and warmer growing seasons, however, could benefit agriculture as long as concerns over reduced soil moisture are addressed. These changes could result in detrimental impacts for ground water supplies,

lake levels and urban environments, and will threaten some species and sensitive natural ecosystems. The climate change issue also has the potential to undermine many of the ecosystem remedial actions undertaken in past.

Although human systems in a watershed may adapt to climate change, albeit at some cost, natural ecosystems and wildlife cannot adapt very quickly to a sudden, large change and hence are at risk. For example, some open shoreline wetlands will migrate lakeward while more enclosed wetlands will dry up, and the resulting habitat changes will have substantial implications for migrating birds and wildlife. Climate change thus adds another layer of stress to species and ecosystems that may already be seriously threatened by impacts from other human activities. These multiple stresses exacerbate local species extinction and enhance the likelihood of invasion by exotic species.

WATERSHED MANAGEMENT ISSUES

Given the nature of the changes which are likely as a result of climate change, we can expect impacts in virtually all aspects of the strategies and procedures currently in place for managing watersheds. For the sake of clarity, some of the key categories and some of the potential impacts are outlined below.

Flood Control

The climate impacts with regard to flood control will be seen through the change in the hydrologic cycle. A change in meteorological inputs will result in changes within the hydrologic flow regime of a watershed. Typical flooding impacts will result from more severe weather giving more intense rainfalls at an altered frequency of occurrence. Additional changes would be an increased number of mid winter

melts as a consequence of warmer winter temperatures. These changes will have varying impacts on individual watersheds and watercourses. Those watercourses sensitive to thunderstorm type flooding may experience more frequent and extensive flooding problems. Watersheds which typically are only impacted by spring snow melt flooding may have a reduced flood risk due to mid-winter snow pack losses or may have risks shifted earlier into the winter period. Changes in the melt of snowpacks, such as earlier snowmelt runoff events may also impact other water management issues such as reservoir operations.

Similar to the issue of flood impacts, a change in intensities and susceptibility to severe thunderstorm type events will tend to reduce the effectiveness of flood warning. These intense storms tend to occur with shorter lead times. Our current forecast abilities fall short in terms of accurate timing and rainfall amount prediction. In addition, with the shift to more intense storms, will come the increase in urban flood issues such as storm sewer surcharging, street flooding and basement flooding. In areas with combined storm and sanitary services, overflows may become more commonplace.

The issue of not only more severe and frequent thunderstorm type events may be compounded by the likelihood of more severe and frequent major tropical storms impacting Southern Ontario. With the likelihood of more frequent or severe Hurricane events, it may simply be a matter of time before a storm at or above the magnitude of Hurricane Hazel impacts the Province. While the Province through its Flood Plain Planning Policy has reduced the impacts of flood damages very effectively, a storm which exceeds current design standards applied would result in significant damages and risk to life within our watersheds.

Current policies in place to deal with flooding will be impacted. These policies range from design

standards for the regulatory flood to the operation of existing structural flood control facilities.

Erosion Control

Watershed Management strategies also have been developed that attempt to mitigate the impacts of urbanization on erosion processes within the basin. Erosion is a natural process related to the fluvial geomorphology of the watercourse. A stable system tends to reflect a balance between erosion and deposition along the watercourse reaches. As noted previously, urbanization has resulted in changes to these processes through changes in the flow regime or the flow conveyance system. Additional changes as a result of climate change will tend to create erosion within stable watersheds and further increase erosion problems within watercourses currently undergoing changes. The low flow channel of a stable river/stream system reflects the need of the conveyance feature related to the bankfull flow need within the watershed. The return period associated with the bankfull, or channel forming flow, is typically defined to be at or near the 1.5 year flow rate. Should climate change lead to increases in the frequency of severe storms and in the frequency of the channel forming flows, it can be expected that our rivers and streams will react to reflect the changes at this flow rate.

An additional area of concern related to erosion centres on a potential increase in freeze / thaw along the stream banks as a consequence of a change in mid-winter melt events. An increase in these events will tend to cause structural failures within the banks, further destabilizing them, increasing slumping and erosion.

Stormwater Management

Stormwater management reflects a program specifically designed to mitigate impacts related to changes within the hydrologic cycle due to urbanization. This program has also evolved from one related to flood and erosion control to one which attempts to deal with issues of both water quantity and quality. With the impacts expected within our watersheds related to flooding and erosion, this program and the hundreds of facilities developed to mitigate urbanization impacts will also undergo significant impacts.

Existing facilities will no longer be in position to provide the levels of quality or quantity control they presently provide, and may in some instances be at risk of failure.

Fisheries Management

Management strategies related to maintaining, enhancing, or developing a sustainable fishery on a watershed basis is one program which directly depends on the flow regime within the basin. The aquatic environment is supported by the base flow within the watercourse, base flow being defined as the input of groundwater flow into the watercourse. The base flow or low flow component of the overall flow regime forms the aquatic habitat which supports the aquatic environment, including fisheries. The likely climate change impacts within the fluvial system will have serious implications on a Watershed's abilities to maintain its current fishery. In addition to these physical impacts, the increase in mean annual temperature will be reflected in the temperature of ground water inputs to the watercourses. Even a small increase in stream flow temperature will result in cold water habitats being lost or seriously degraded. Temperature changes have the potential for a major shift in the type of fishery that the watershed may be able to support, regardless of any habitat issues.

Terrestrial Management

Watershed Management programs and policies also encompass terrestrial habitats as well as aquatic. Identifying Environmentally Significant features, such as forest blocks, wetlands, valley and stream corridors, and developing policies or procedures to protect and enhance these features is a major component of management strategies. These features contain functions related to the flora and fauna within them, provide a social function for the residents of the watershed, and provide benefits related to the hydrologic cycle.

Changes within the climate will result in significant impacts and changes within these features as well. The increase in temperatures will extend growing seasons and allow for additional plant species to enter the watershed, many of which could very well be invasive and force changes in the existing biodiversity. The changes in temperature may also allow for a movement of additional animal and bird species into the watershed or the movement out of or extinction of existing species. Changes in meteorological inputs such as extended drought periods will also create stress within the flora and fauna, resulting in changes such as population reductions in some species or the eventual replacement with species of flora and fauna more resistant to these types of climate changes.

An Integrated Mapping and Assessment Project or IMAP (MacIver and Auld 2000) was launched in January, 1999 to integrate atmospheric change with land use, biodiversity and other issues. Early integration and mapping efforts have shown strong support for several scientific hypotheses: (1) available heat is a powerful trigger in the natural world; (2) atmospheric heat has a significant influence on land use change and biodiversity, particularly in rural areas; and (3) subtle warming of a degree or two Celsius could significantly change land use, landscapes and the biodiversity of southern Ontario. The results indicate that summer heat, as measured using Corn Heat Units (CHUs), can be linked historically to the disappearance of inland wetlands and of remnant Carolinian woodlots. CHUs indicate

the warmth available for crop maturation during the growing season. Results suggest that subtle warming in areas with fair to good soil quality may lead to economic pressures for the elimination of many natural habitats by making these rural areas profitable for more intensive agriculture (MacIver and Auld 2000). For example, results indicate the potential for greater pressures encouraging loss of remnant Carolinian woodlots in southern Ontario as the climate warms and CHUs increase. As the Figure below indicates, for areas with fair to good agricultural soils, the 3200 CHU contour reasonably delineates warmer areas with significant loss of remnant woodlots. As the 3200 CHU contour moves northward under climate warming, new areas of southern Ontario may experience additional pressures for the removal of woodlots. Similar results were shown for the historical loss of inland wetlands, with the 2800 CHU contour generally delineating areas with greater loss of wetlands .

Present Landcover and Threshold Corn Heat Units (2900, 3200)

Source for Land-use Mapping: Ministry of Natural Resources, 1995.

Source for Climate: Watson and MacIver, 1995.

Other IMAP results, using forest biodiversity plots measured following international biodiversity protocols, indicated that the biodiversity of forests in south-central Ontario increased directly and nearly linearly with atmospheric heat, as shown in the Figure below. Atmospheric heat is measured using Growing Degree Days, a quantity similar to CHUs but representative of a longer season. These results, which suggest that a warmer climate will eventually support greater forest biodiversity, have implications for future conservation practices and imply the need to consider the role that exotic and invasive species will play in increasing this biodiversity.

Watershed Management strategies inherently reflect policies and programs with a degree of flexibility or

dynamism as they are designed to deal with natural systems and processes which are constantly undergoing change. As such, many of the strategies also provide a basis to evolve to include the flexibility to deal with changes in the natural and atmospheric systems brought about through climate change. The following represent areas where change in policies or programs can and will be necessary if Watershed Management is to continue as a viable ecosystem based management structure.

Climate and Mixed Hardwood Family Tree Biodiversity- Southern Ontario (expressed as number of families).

Data Sources: EMAN, ACER, NEC, Environment Canada, Ontario Ministry of the Environment, Boyne Education Centre, Long Point Biosphere Reserve, Conservation Areas and Boards of Education.

Adapting Watershed Management to Climate Change

Climate change will affect all aspects of our ecosystem and we lack a great deal of specific information to comprehensively address each individual issue, however the following reflects some areas where adaptation may be required.

Surface Hydrology

Modelling of the surface hydrology within a watershed should be updated to allow for impacts of climate change to be analysed. Models based upon a continuous flow simulation, and based upon a water budget approach, will allow for a series of climate variations and their impacts to be reviewed and

sensitivities and trends of potential impacts identified. Once completed, regulatory flood standards will be assessed, revised bankfull flow estimates defined, and strategies developed to address these flow changes. Policies and procedures need to be developed to deal with the changes in the fluvial components of a watercourse, such as erosion, and meander belt movements to allow for revised channel design standards, and remediation. Planning related to impacted infrastructure such as bridges, culverts, sewers, and outfall structures, needs to be addressed. Flood risk planning and remedial works associated with minimizing future flood vulnerabilities can be identified, prioritized, and undertaken as required. Operational viability of existing flood control structures can be assessed, and operational modes revised to account for a revised flow regime, as detailed climate change assessments are developed.

Aquatic Environment

Fisheries management plans will be revised and updated to reflect the most effective way of dealing with climate change impacts through identification of resources which will be sensitive to climate impacts. The management plans will then reflect how these resources could then be protected, enhanced or managed to reflect the long term habitat and species changes.

Terrestrial Environment

Terrestrial natural heritage strategies will include policies and programs which allow both the adaptation of planting, restoration, and management plans to reflect climate change and also to allow for the mitigative aspect of the terrestrial environment as a carbon sink to assist in reducing greenhouse gases in the atmosphere.

CLIMATE CHANGE SCIENCE NEEDS

To define the impacts of climate change at a level of detail where effective adaptation can be incorporated into Watershed Management, a great deal of additional study and information will be required. Several areas of additional need are:

- A much more defined assessment of climate impacts on a watershed or a regional scale is required to facilitate any form of modelling and assessment.
- Climate projection improvements should be an assessment of storm frequency change as the typical design approach of looking back to plan forward will likely not remain as a functional tool.
- An assessment of major weather events such as hurricanes and their potential impacts on the Province.
- Studies to look at evaporation changes and their potential impacts to lake levels, droughts and the terrestrial environment.

The impacts and resultant changes that are anticipated from climate change on all the natural features and processes presently managed on a watershed basis will be occur over a time frame stretching into the second half of this century. Watershed Management plans are documents which incorporate policies, strategies, and programs designed to manage natural processes over an extended time frame, and as such, provides the ideal platform, and set of tools to allows for adapting to climate change.

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