Adapting to Climate Change in the Maitland Valley Watershed, Ontario: A Discussion Paper for Watershed Stakeholders

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Preface

The research presented in this report was supported by a grant from the Climate Change Action Fund. We are grateful to the numerous people in Ontario who participated in the study by supplying resources and their time.

Additional material on the physical, institutional, and human characteristics of the Maitland watershed is available on the website created for this project, located at:

http://www.uoguelph.ca/gwmg/wcp_home/Pages/M_home.htm.

More information about the objectives and progress of this study can be found at:

http://www.uoguelph.ca/gwmg/ccaf02.htm

Executive Summary

Changes in the availability of water due to climate change could affect water-dependent industries and communities in the Maitland Valley watershed, making it important to examine strategies for coping with climatic variability and change. The extent to which a watershed community is vulnerable to the impacts of climate change is partly determined by its ability and willingness to take measures to adapt. In the Maitland watershed, groundwater studies for Huron and Perth counties have concluded that local groundwater resources are more than adequate to meet current and future water demand. Despite the relative abundance of groundwater, water scarcity as a result of climate change could still pose problems for water-dependent human and natural systems in the Maitland watershed. For instance, at many times of the year flows in the Maitland River and its tributaries are low to non-existent. Past alterations in the landscape, such as draining of wetlands and clearing of land for agriculture, have resulted in reduced baseflows. Climate change could thus exacerbate existing surface water scarcity caused by landscape changes.

Agriculture is the primary land use in the Maitland watershed and a cornerstone of the economy; it is highly susceptible to current climatic variability, and is likely to be significantly affected by increased climatic variability resulting from climate change. At present, local solutions for coping with variability in water supplies are short-term in scope, and do little to address the long-term implications of current water use practices. Due to the potential impacts of water scarcity on local economic, social, and ecological interests, adaptation to climate change within specific sectors (e.g., agriculture, inland fisheries) should be considered.

The purpose of this research was to analyze ways in which institutional arrangements for water management facilitate or constrain capacity to adapt to climate change at the watershed scale in the Maitland River basin. This report presents findings concerning the nature and extent of adaptive capacity in the Maitland River watershed through the use of local examples, and presents several recommendations for building capacity at the watershed scale. A central objective of this document is to provide an opportunity for watershed stakeholders to comment on this ongoing research.

The project consisted of a review of local and provincial institutional arrangements for water management. Sources included legislation, policies, regulations, reports, newspapers, academic literature, and websites. In addition to document analysis, interviews were conducted with local and provincial officials knowledgeable about water use, programs, and climate change, particularly within the Maitland watershed.

While the research brought to light many challenges for water allocation and management at the provincial scale, only those with implications for the Maitland watershed are outlined here. The recommendations pertain to three major categories of discussion: 1) the Permit to Take Water program; 2) short-term actions taken by watershed stakeholders to cope with periods of low water; and 3) long-term strategies for protecting groundwater recharge areas and conserving water. A major challenge in the Maitland watershed will be altering existing attitudes and water use practices to better consider the potential effects of climate change on land use, the need for long-term protection of water resources, and the role water conservation is likely to play in adaptation to limited water availability.

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1. Introduction

Changes in air temperature, precipitation, and the frequency and severity of drought events related to global climate change could adversely affect agriculture in the Maitland watershed [43]. The capacity of the Maitland watershed community to adapt to climate change is, in part, a function of the extent to which watershed organizations and individuals have the tools, authority, understanding, willingness, and resources to undertake management options to reduce the vulnerability of social and economic structures reliant on water resources. The Maitland watershed community's adaptive capacity will differ from that of other regions in Ontario and elsewhere, as it is influenced by distinctive local and regional factors. The aim of the research underlying this discussion paper was to identify barriers to adaptation within the watershed, to illustrate some of the strengths and weaknesses in existing institutional arrangements for water management, and to suggest ways to increase adaptive capacity and reduce the area's vulnerability to climate change. In this discussion paper, the term "institutional arrangements" refers to provincial laws and regulations, local by-laws and plans, policies, guidelines, and the various organizations that are involved in water management and land use planning.

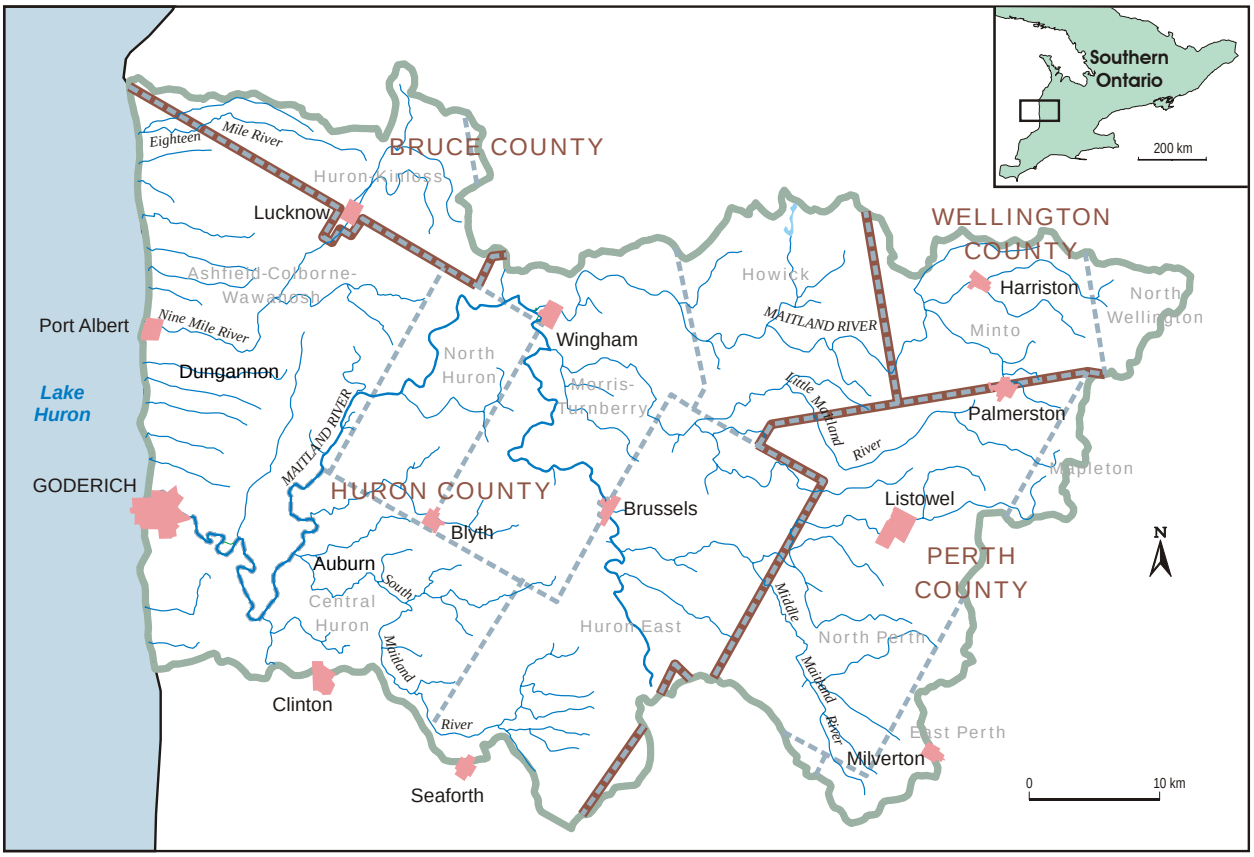
1.1. Potential Effects of Climate Change on the Maitland River Watershed

The Maitland River watershed covers an area of approximately 2,500 square kilometres on the shores of Lake Huron (Figure 1) in southern Ontario. The watershed extends from the southern portion of the Township of Huron-Kinloss in the north to the community of Clinton in the south. The headwaters of the Maitland River are located in the eastern portion of the watershed in Wellington and Perth counties.

In 2001, the population of the watershed was approximately 60,000 people. The Town of Goderich is the largest settlement, with a population of nearly 7,600. Communities in the basin are largely reliant on groundwater for domestic and municipal water needs, except for Goderich, which obtains its water supply from Lake Huron. Agriculture is the dominant land use in the region, covering over 80 % of the landscape. Cash crops, such as corn, wheat, and soybeans, and livestock are key agricultural products. A trend towards larger-scale, more industrialized agriculture has resulted in moderate to high concentrations of livestock in the watershed (40-120 animal units per 100 hectares) [7]. Consequently, livestock watering is a major water use in the basin. Under climate change, increased demand for domestic and agricultural water uses may exacerbate low surface water flow periods and lead to depletion of groundwater resources.

Projections of climate change for the Great Lakes Region suggest that higher air temperatures and lower streamflows can be expected in southern Ontario [37, 49, 50]. Temperatures in the Great Lakes basin, of which the Maitland watershed is part, are projected to increase by 1.2°C to 9.1°C in the winter, and by 0.6°C to 8.6°C in the summer [49]. Warmer water temperatures and decreases in summer streamflows are expected in areas dominated by snowmelt and subject to climate change [14]. Additionally, rising evaporation rates caused by higher average air temperatures will likely counteract any potential increases in precipitation, resulting in lower streamflows and groundwater levels [49].

Figure 1: The Maitland Watershed, Ontario



Increased climatic fluctuations and declines in groundwater and surface water levels in Lake Huron, the Maitland River, and its tributaries have the potential to affect many sectors [14]. Of particular concern, higher air temperatures and reduced summertime precipitation could seriously disrupt agricultural production in the Maitland watershed. In this area, there have traditionally been regular snow accumulations in winter and melts in spring that maintain soil moisture, and sufficient rainfall at appropriate intervals during the growing season to support an extensive agriculture industry. Consequently, to date there has been little emphasis on the potential effects of limited water resources on agricultural production.

A recent study, however, suggests that precipitation in the Maitland Valley has become increasingly variable, and that high intensity storms have become more common over the past forty years [44]. More frequent high intensity storms resulting in high streamflow events have increased the average annual streamflow, but have not led to higher streamflows during dry periods [44]. The impacts of less frequent but more intense rainfall events, and the impacts that extended periods without precipitation will have on soil composition and plant growth, are important considerations for the agriculture industry. Ultimately, to cope with these conditions, the industry may need to adapt by varying the types of crops chosen and by utilizing practices to increase soil moisture and retention (e.g., raising the organic content of soils).

Intense rainfall and higher water temperatures could impair surface water quality by washing land-based pollutants into rivers and promoting growth of bacteria and algae [31]. Current water quality conditions have already led to algal production in streams and in the near-

shore areas of Lake Huron, and are a prominent concern in the watershed [4, 36, 46]. The predicted changes in climate could exacerbate existing surface water quality problems.

Historic clearing of land to increase the productive area for agricultural purposes has resulted in drainage of low lying lands and wetland areas, and deforestation. These practices have heightened the area's susceptibility to drought, since less water can be stored on the surface of the land. This has reduced infiltration, groundwater recharge and baseflow contribution to streams. Furthermore, the extensive adoption of tile drainage throughout the southern and eastern reaches of the Maitland watershed may in fact limit the capacity of agricultural stakeholders in the watershed to adapt to climate change. Tile drainage does not promote retention of soil moisture, a key variable of concern in agricultural areas susceptible to changes in climate [36].

Climate change is also likely to have implications for recreation, cold-water fisheries, municipal water supplies, and public health in the Maitland watershed. For instance, lower streamflows in the Maitland River and its tributaries could further hinder recreational uses (e.g., swimming and canoeing) already marginalized by low and variable flow conditions, and combine with warmer water temperatures to adversely affect fish habitat. Increased domestic, industrial, and agricultural water use could strain groundwater supplies. Additionally, expected increases in the frequency and severity of extreme weather events, such as flooding and drought, could compound other issues (e.g., water quality problems).

1.2. Water Management and the Capacity to Adapt to Climate Change

The ability or capacity of a community to adapt to climate change is a function of the manner in which water resources are managed and allocated, among a host of other factors. Adaptive capacity is a concept widely accepted in the climate change literature [54, 59]. It usually refers to the adaptability of a nation, society, organization, group, or community (i.e., people living or working in a specific locality, such as a watershed). Adaptive capacity in the water sector is dependent, at least in part, on institutional factors such as the availability of implementation resources and knowledge, the legal authority to make necessary decisions, and the flexibility of institutional arrangements for water management. In the context of an agricultural watershed community, adaptive capacity is greatly influenced by the capacities of organizations (both governmental and nongovernmental) and individuals (agricultural operators and other rural landowners and residents), and the nature and strength of inter-organizational, inter-sectoral, and inter-personal networks. Adaptive capacity is important because it helps to reduce a community's vulnerability to periods of drought and water shortage.

There are two major provincial institutional arrangements for water quantity management in Ontario: the Permit to Take Water Program (PTTW), the primary water allocation mechanism under the *Ontario Water Resources Act*; and the Ontario Low Water Response (OLWR), a framework for drought management created in 1999 by the Ontario Ministry of Natural Resources in collaboration with several other ministries and organizations with roles in water management. Recently, administrators of the PTTW program have been criticized for making permit decisions with inadequate knowledge of existing water resource availability and appropriations, and insufficient consideration of integrated water management principles [22, 23]. The PTTW program largely relies on permit holders to reduce water use in the event of interference with other users or the natural environment. To address these concerns, the Province of Ontario proposed amendments to the *Water Taking and Transfer* regulation (285/99), established pilot projects, and re-established the Provincial Ground Water Monitoring Network. Use of the watershed as a water management unit has been a notable feature of some recent and

proposed changes to institutional arrangements for water quantity management. Further changes have been proposed in the recently released *White Paper on Watershed-based Source Protection Planning* [52].

The watershed has long been considered an "optimal unit" for management and planning of water resources. Watersheds are complete hydrologic units, and an appropriate scale for promoting the sustainability of water use [42, 52, 61, 62]. Ideally, watershed management considers the cumulative effects of water takings on water resource availability [5]. While regional groundwater systems may extend across surface watershed boundaries, the watershed unit allows for better consideration of surface water – groundwater interactions, and facilitates planning across jurisdictional boundaries. Use of this approach could aid adaptation to climate change by considering the long-term sustainability of different water management options [34].

It is appropriate to consider the watershed context when making decisions about water allocation under climate change, since actions taken upstream have implications for downstream water users [2]. For these reasons, this research focuses on water allocation and water-related land use planning at the watershed scale, and considers the authorities, tools, and challenges of water allocation and water quantity management within the Maitland watershed.

Water allocation systems guide decisions about who gets water, how much water they get, and when they get it. Water allocation goals may include conservation, drought management, promotion of sustainable growth and development, or protection from the consequences of more severe or frequent low-water conditions due to climate change [19]. The climate change adaptation literature suggests options for responding to increased demand for water and limited water resources. Traditionally, water quantity management has focused on supply options (e.g., building dams, locating new sources of water). Supply management might also include protection of groundwater recharge areas and wetlands to promote infiltration. More recently, demand side management and planning options have gained favour [21, 54]. Examples include long term water servicing planning, water conservation (e.g., adoption of more efficient technologies or practices), and changes to land use practices (e.g., types of crop grown, adoption of irrigation). Demand management may also take the form of changes to institutions for governing water use in order to increase flexibility or appropriateness under changing climatic conditions. Options for adapting to limited water supplies and increasing demand for water range from those that could be adopted at the provincial scale (e.g., drought management guidelines), down to the scale of an individual landowner’s property (e.g., new irrigation technologies). In this respect, not only do the water management activities of organizations (e.g., provincial government, conservation authorities, municipalities) contribute to adaptive capacity, but the water management behaviour of individuals, particularly farmers in an agricultural watershed, is also important. Water-related decision-making by farmers is influenced by a myriad of factors, such as senior government economic and agricultural policies.

A key consideration for adaptation is the extent to which water managers assume that future availability of water resources will be the same as it has been in the past, and base their decisions on historic precipitation levels and patterns. These approaches constrain adaptive capacity by limiting water managers’ ability to take a precautionary, or planned, approach to mitigating the impacts of climate change.

2. Research Approach

The climate change adaptation literature recognizes that adaptive capacity is influenced, in part, by the way institutional arrangements are structured, and their flexibility, legitimacy, and integration [2, 12].

- Flexibility is the ability to change water allocation structures in order to accommodate alternative, competing, or additional water uses.
- Legitimacy is facilitated by incorporation of meaningful stakeholder involvement, definition of clear roles and responsibilities for water management, existence of checks and balances within the water allocation process, and granting organizations appropriate authority to manage water resources and water-related land uses.
- Finally, integration is enhanced by consideration of all water uses (including environmental uses), incorporation of water-related land use planning, and stakeholder involvement on a watershed scale which includes upstream and downstream interests.

Targeted questions were used to determine the extent to which institutional arrangements for water allocation and planning facilitate or constrain adaptive capacity at the local level in the Maitland watershed (Box 1). In Canada, provinces dominate the development and enforcement of laws and regulations relating to water management, but local level organizations, such as municipalities and conservation authorities, are often major players in program implementation. The indicator questions guided a review of documents relating to institutional arrangements for water allocation (e.g., PTTW and OLWR), including legislation, regulations, reports, meeting minutes, newspaper articles, websites, and academic journal articles. In addition to the document analysis, 15 key informant interviews were conducted with local and provincial level persons with responsibilities for water allocation (OMOE) or management (MVCA), familiarity with water resources or climate change (e.g., MVCA, The Lake Huron Centre for Coastal Conservation), or responsibilities for water-related land use planning (e.g., municipalities). Interview questions were based on the indicator questions in Box 1, and tailored to the individual's or organization's role and experience with water management, and knowledge about climate change.

Importantly, Box 1 is not a comprehensive list of all indicator questions used. Instead, it is a sample to demonstrate the type of information sought. The indicator questions in Box 1 are not targeted to any level of organization or scale of analysis, since it was recognized that some indicator questions were more appropriate for a provincial focus, while others dealt more with implementation, policy, and knowledge at the local level.

Box 1: Examples of indicator questions for flexibility, legitimacy, and integration.

Flexibility

- What discretionary powers, if any, do authorities have to restrict license or permit issuing to protect groundwater or surface water supplies? Is there authority to consider such restriction at a watershed scale?
- To what degree could limitations be placed on a license or permit to protect resources for periods of low water as a result of climate change?
- Do provincial policies make appropriate assumptions about resource availability both at present and under potential climate change? How, or to what extent, are these policies and arrangements relevant at the watershed scale? Are there inherent provisions for uncertainty in resource availability?
- To what extent are there opportunities under existing legislation, regulations, or policies to permit informal allocation of resources among stakeholders?
- Do present water allocation rules in each watershed permit re-allocation of water to reflect potential changes in the availability of the resource and sectoral or individual need?

Legitimacy

- Is there transparency in the water allocation process? To what extent is stakeholder participation provided for within the institutional arrangement for water allocation?
- To what extent are there inherent checks and balances within institutional arrangements for water allocation?
- To what extent are the roles and responsibilities for various agencies outlined?
- To what extent do the specific arrangements support the stated overall goals and objectives?
- To what extent does authority for the adoption of adaptive measures exist at appropriate scales (local vs. watershed/basin, or provincial)?
- To what extent are expectations of local agencies consistent with transfer of authority and resources to adequately manage those responsibilities?
- Do the authorities have appropriate and/or exclusive jurisdiction over the resources?

Integration

- To what extent do institutional arrangements promote adoption of additional adaptive measures for periods of low water?
- To what extent do institutional arrangements promote demand-side management and long-term protection of water resources through water-related land use planning and other practices that increase adaptive capacity?
- To what extent do institutional arrangements address the effect that a given arrangement will have on related institutions and institutional arrangements?
- To what extent do institutional arrangements provide for input about the development, implementation, and evaluation, of a program/policy/adaptive measure from a variety of senior agencies, other than the primary implementing agency?

3. Findings and Discussion

Adaptive capacity in the Maitland watershed is a function of individual and organizational access to implementation resources, such as money, trained staff, and leadership, which have influenced the current level of adoption of adaptations; legal authority and other institutional considerations; the ability of water managers and others to assess current and future water needs; and water management processes, for instance stakeholder participation in decision-making and motivating adaptive behaviour. Each of these factors is influenced to varying extents by the flexibility, legitimacy, and integration of institutional arrangements for water and water-related land use management. The following discussion highlights factors that are found to be facilitating or constraining adaptive capacity in the Maitland watershed.

3.1. Implementation Resources

Much of the academic literature on capacity in the water sector identifies the need for organizations managing water resources to have adequate financial, technical, and human resources [1, 10, 20, 33, 54]. Less commonly acknowledged, yet important, resources include leadership, the range of available alternatives for adapting to climate change, and the ability to resolve conflicts. When it comes to resources, watershed scale adaptive capacity is largely determined by the capacity of municipalities and other organizations (e.g., Maitland Valley Conservation Authority, local stewardship groups) in the watershed, although the capacity of individuals, particularly farmers, also is important.

Financial Capacity

Capacity is largely dependent on the financial resources that enable an organization or individual to undertake actions they deem necessary in order to improve water quality and quantity management. The Maitland Valley Conservation Authority (MVCA) has been successful in obtaining funding, in addition to that provided by municipalities, from Human Resource Development Canada to establish the Maitland Watershed Partnerships and fund specific projects under the partnership umbrella [46, 55]. Funding has generally been available for case- or site-specific projects, such as water contaminant testing under the River Health Framework [46]. However, these project-based sources of funding are inadequate to support long-term monitoring and investment in human resources. The MVCA is limited in the types of activities it can undertake by the restrictions and targeting of existing funding arrangements and operating budgets [6].

In 2002, MVCA entered into a contract with the provincial government (OMOE) to monitor groundwater levels and quality in 12 wells established under the 6-year Provincial Groundwater Monitoring Network. Under the agreement, OMOE provided funding to drill 5 wells and instrument 12 wells [38]. MVCA secured one-time funding to drill the remaining wells, but remains responsible for costs associated with data collection and water quality testing for the duration of the project [15]. While MVCA acknowledges the benefits of long-term monitoring for water-related planning, OMOE's limited financial commitment is likely to limit the longevity of the monitoring network since the funding has been insufficient to offset costs downloaded to the MVCA [15, 40]. Conservation authorities (CAs), including the MVCA, are incurring unplanned and unforeseen costs associated with locating suitable wells and monitoring [63]. Long-term monitoring could provide necessary information about groundwater resources to

make more sustainable decisions about water taking permits, and could enhance the community's adaptive capacity.

The recently released White Paper on source water protection [52] sets out the Province's commitment to watershed-based source water protection, in response to the contamination of Walkerton's drinking water supplies. According to the White Paper, CAs will have key responsibilities for source protection planning, by serving as Source Protection Planning Boards responsible for, among other things, setting the Terms of Reference for source protection plans, ensuring that plans comply with the Terms of Reference, resolving any conflicts surrounding the plans, and seeking municipal support for the plans [52]. There will be financial and other resource implications for CAs, including the MVCA, as a result of these emerging responsibilities.

Leadership and Human Capacity

Human resources are an important component of adaptive capacity. Key aspects are the availability of qualified, knowledgeable staff, and individuals or organizations that adopt leadership roles. Strong leadership within an organization, and the existence of a lead organization within a watershed (or individual within a community, such as the agricultural community), facilitate adaptive capacity. MVCA has demonstrated leadership by bringing together various stakeholders and stakeholder groups to identify water related needs and directions for research in the watershed, and obtaining funding through the Maitland Watershed Partnership established in 1999. These leadership and partnership activities strengthen MVCA's capacity, and the capacity of the broader watershed community, by influencing awareness, project development, and reporting throughout the watershed. The development of the Maitland Watershed Partnerships has been effective in bringing together a local decision making group to prioritize watershed management issues (it also serves as the Ontario Low Water Response Team) and initiatives (e.g., source protection planning).

Range of Alternatives

In the Maitland, the range of alternatives for adapting to climate variability and change is influenced by the relative abundance of groundwater resources. In the past, there has been limited concern about the scarcity of water; replacement wells were drilled when supplies seemed insufficient. Additionally, some municipalities pointed out that they are relatively close to the Great Lakes, should additional water resources be required. However, pipelines to the Great Lakes are controversial solutions to water supply problems, since they are costly and face other challenges, such as lower lake levels due to climate change and increased demand for Great Lakes resources by municipalities in both Canada and the United States. For the most part, watershed municipalities have shown little concern about the potential for water scarcity, or the consequences of climate change for long-term planning and water resource availability.

There are a few examples of municipalities in the Maitland watershed altering water use practices to encourage long-term water conservation, an important component of sustainable water management [9]. For instance, the Town of Goderich has planted drought resistant grasses in some public areas, such as boulevards. Furthermore, all municipalities in the watershed that own or operate public water works have adopted some type of by-law to restrict outdoor water use, mainly landscape watering, through time of day and alternating day restrictions. In some cases (e.g., Township of Huron-Kinloss, By-law 99-61), by-laws are in effect year round and don't require a council resolution to enforce them, which facilitates use of the by-law.

Municipalities made limited use of other demand side management approaches. For example, water use metering occurs in Goderich and Wingham, and in new developments in Listowel, but no municipalities have developed extensive education programs, or sponsored household or commercial retrofitting programs to promote more efficient water use fixtures (e.g., showerheads, toilets, etc.). Water main leak detection programs were not found to be common.

An important consideration for the Maitland watershed is the range of alternatives for adapting to climate change in the agriculture sector. Adaptation could take the form of changes in management practices, or adoption of new technologies. Agriculture has played a significant role in the historical development of the region, and continues to be the dominant land use in the watershed. Municipalities in the watershed have identified agriculture as an important industry, both in economic and social terms. Indeed, the central importance of agriculture is confirmed in Huron County's Official Plan, which articulates the social, economic, and political importance of farming. The plan outlines issues key to the future of agriculture, including maintaining ability to farm, preserving prime agricultural land, and recognizing that the quality of life for future generations is linked to the establishment of a healthy agricultural and rural economy [17]. Agriculture is significantly affected by changes in climate averages, and to a greater degree by the changes in the frequency and magnitude of extreme events. In the Maitland watershed, it is expected that precipitation events will become less frequent, but more intense, and that temperatures will rise, causing increased evapotranspiration and reduced soil moisture.

Agricultural production in the Maitland is a combination of livestock rearing and crop production. Currently, cropping systems in the region, while economically important, are not well suited to irrigation because of the expansive nature of production and attainable margins. Thus, if irrigation becomes necessary to offset warmer, drier summers with less frequent, more intense rainfall events, producers might be compelled to switch the types of crops being produced. While a switch to higher value crops to justify the investment in irrigation might be possible, especially in areas with lighter soils that are suitable for fruit and vegetable production, soil and temperature conditions still may be limiting. Adoption of irrigation is also influenced by non-climatic factors, such as the financial security resulting from producing a successful crop annually, and being able to rely on the quality of the crop (e.g., apples are the right size and quality to be sold) [53].

Institutional arrangements may also come into play. For instance, farmers may face pressure to irrigate in order to receive crop insurance, or to lower insurance premiums, and to be viable and competitive in the marketplace. Irrigation is one form of adaptation that will directly affect water allocation and use in the Maitland Valley [43]. If climate change proceeds without complementary changes to cropping systems, then the vulnerability of an important socio-economic activity the in the region is likely to rise. The intermittent nature of surface water flows and higher evaporation rates expected under climate change suggest that, in the Maitland watershed, irrigation would draw from groundwater sources. Other adaptations that may be necessary to maintain the viability of agriculture could include increased adoption of more ecologically sound farming systems, agro-forestry, multiple cropping techniques, best management practices to raise the content of organic matter in soils, and selection of more drought tolerant crop types [43]. A major limitation on adaptive capacity in the agricultural sector is scepticism within the community about the nature and degree of potential impacts associated with climate change, and the understandable tendency for producers to focus attention on problems at hand, which, unfortunately, are numerous in the Maitland Valley watershed, and elsewhere in Ontario.

Conflict Resolution

There has been little conflict over water resources in the Maitland because of the significant groundwater resources available in the watershed. Local groundwater studies for Perth and Huron counties confirm that groundwater resources are adequate for current and future development [32, 60]. As noted earlier, past water supply problems have been resolved by securing new supplies (e.g., domestic wells dug into overburden were deepened to draw from bedrock resources), and changing operating practices (e.g., lowering pumping rates to avoid well interference in Atwood [3]). To date, development has not been limited by water quality, quantity, or reliability. Since surface water supplies in the Maitland River and its tributaries have historically been variable, there has been little reliance on these sources for domestic, industrial, or agricultural purposes.

Patterns of water use, and the way water use information is collected, influence the ability of local agencies to identify and address water-related conflicts in the early stages. For instance, water takings for livestock watering drawn directly from a source without using storage do not require a permit under the *Ontario Water Resources Act* (PTTW program), even if they withdraw more than 50,000 litres/day. In several areas of the Maitland watershed, applications are made each year for water takings for large livestock operations intending to store water for livestock watering. Monitoring and reporting of water use is limited under the PTTW program, but since permits are not always required for livestock watering, this water use would not be accounted for even with the adoption of monitoring and reporting under the program. While agricultural water use can be estimated from livestock census data and coefficients for agricultural water use [35], actual water use data is unavailable. Additionally, little is known about the cumulative volume of water takings, agricultural and other, that withdraw less than 50,000 litres of water a day. This knowledge gap could be a significant constraint on assessing the cumulative effects of water takings and the impacts of additional takings, particularly if there are increased demands for irrigation from groundwater sources. Furthermore, since permits are not required for livestock watering, neither MVCA nor municipalities have the opportunity to comment on the implications of the takings, making interference between agricultural and other water takings more likely. Intensification of the livestock industry in the northern portion of the watershed could exacerbate conflicts over water use.

3.2. Legal Framework

The legal framework for water management is a strong determinant of the adaptive capacity of watershed organizations for coping with periods of drought and water shortage, which strongly influences the adaptive capacity of the broader watershed community. Literature on adaptation to climate change confirms the profound influence of institutional arrangements on adaptive capacity [20, 54]. Key issues are the legal authority of an organization to adapt to climate change, and the ways in which institutional arrangements constrain adaptation.

Authority to Act

Watershed scale management of water resources is a common theme in recent provincial initiatives, such as the Ontario Low Water Response drought management guidelines, the Provincial Groundwater Monitoring Network, and recommendations associated with source water protection (e.g., from the Walkerton Inquiry [51], and Credit Valley and Grand River conservation authorities [19]). The literature identifies a watershed approach as appropriate for water management and integrated resource management. Unfortunately, legal authority for water

management is not always vested in those organizations best positioned to manage water resources.

Adaptive capacity in the Maitland watershed is constrained by the way programs like the OLWR are designed to interact with local authorities. The MVCA, like other CAs, is responsible for facilitating a Water Response Team (WRT), in order to make decisions about low water response in its watershed. The OLWR allows WRTs flexibility in making recommendations for local response to changing water conditions. However, while the WRT and MVCA may make recommendations, authority for restricting actual water use is limited to municipalities (under Section 12 of the *Public Utilities Act*) in the case of municipal water customers, and the Director appointed under Section 34(6) of the *Ontario Water Resources Act* in the case of permitted water takings. This means that the WRT can develop recommendations and facilitate coordination of non-regulatory options for water sharing within the watershed, but is reliant on local municipalities and PTTW holders to voluntarily implement water conservation when requested. Reliance on voluntary action makes education, local commitment, and program legitimacy key to program implementation, and its effectiveness for reducing vulnerability to climate change.

Another limitation on adaptive capacity is the minimal influence CAs and municipalities have had on approvals for water takings under the provincial Permit to Take Water Program, a common criticism of the program [5, 22, 23]. Currently, some applications for permits are posted to the Environmental Registry under the Environmental Bill of Rights, but not all are posted (e.g., permits for irrigation and most municipal takings are exempt), and while some CAs and municipalities work closely with OMOE, not all CAs and municipalities are directly informed of permit applications. Proposed amendments to the *Water Taking and Transfer* regulation (285/99), supported by the former Conservative and current Liberal provincial governments, would entitle municipalities and CAs to see and comment on permits for water takings [24, 52]. While that cooperation may improve water allocation decision making, conservation authorities and municipalities may not have the human resources to make effective use of the opportunity. OMOE and Conservation Ontario are negotiating the role to be played by conservation authorities in the PTTW program, and what, if any, expectations would be associated with the role [48, 63]. In the past, conservation authorities and municipalities have made arrangements with OMOE to comment on permit applications for takings exceeding a certain minimum volume, or for a specific purpose [27]. Involvement in the permit granting process would enable local organizations to draw attention to concerns about particular takings, consider cumulative impacts, and identify potential conflicts over water resources, under current and changing climatic conditions.

A constraint on adaptive capacity is the lack of legal authority for watershed planning in Ontario. For many years, MVCA has engaged in floodplain mapping and provided municipalities with tools to make zoning and planning decisions that affect the floodplain. MVCA has also been a proponent of naturalization of river banks (e.g., protection of Blyth Brook under the Village of Blyth Greenway Project), and an advocate for protection of wetlands, significant recharge areas, and riparian corridors [46]. However, municipalities, under the guidance of the Ontario Ministry of Municipal Affairs and Housing, have authority for actual land use planning under the *Planning Act*, and are not required to heed watershed planning recommendations to protect recharge areas or other sensitive water supply areas. While municipalities are required to have regard for Provincial Policy Statements, which contain a general statement pertaining to protection of water quality and quantity, there is no formal recognition of watershed planning in the policy statements.

County-level official plans outline general policies for having regard for natural and sensitive areas, but, in most cases, lower-tier municipalities determine the extent of implementation of these policies in land use planning. For instance, Huron County's official plan [17] states that water resources will be protected by amending lower tier official plans to incorporate and implement recommendations from watershed management plans. The County and lower tier municipalities are to contribute to sub-watershed management studies [17]. In another example, Perth County's official plan allows for protective designation of environmentally significant areas and groundwater recharge and discharge areas (Section 11.5.8) [18]. However this designation has rarely been used to protect groundwater resources [26]. An exception is protection of recharge areas identified by MVCA in the former Elma and Wallace townships [18], but even in this instance, there was little awareness at the County level of the extent to which zoning tools were used to protect the identified recharge areas. At the lower tier municipal level, the degree of protection for river courses and sensitive areas is variable. Some official plans outline specific, graded, degrees of protection for identified areas (e.g., former Township of West Wawanosh, in Huron County [16]), while others offer only general statements advocating protection of natural resources, without identifying particular areas.

In the past, MVCA has made recommendations to municipalities about planning in sensitive water resource areas, including floodplains, river valleys, wetlands, forests, headwaters, groundwater recharge areas, and stream corridors. With respect to source water protection, concerns relate to the extent of planning restrictions needed to protect sensitive areas, and municipal willingness to zone restrictively in these areas [56]. While Ontario has a strong tradition of watershed planning, local watershed organizations have little authority to do more than make recommendations when it comes to water allocation and adaptation of local water management to climate change. However, recommendations for consistency between source protection planning and decisions on water taking permits may assist in integration of water quality and quantity management, and enhance local influence over water allocation [51, 52].

Institutional Constraints

In Grey and Bruce counties near the Maitland, and some areas of eastern Ontario, where source water quality is high, questions have been raised about municipal authority to regulate water bottling companies using land use planning powers under the *Planning Act*. A key concern about large water takings for bottling is the impact the takings could have on regional groundwater systems that transcend surface watersheds. Lack of understanding about current water use constrains current abilities to evaluate additional water takings and future sources of supply in the Maitland watershed.

Local implementation of the OLWR has been challenged by differences in approaches for assessing low water conditions. Under the OLWR, conservation authorities are responsible for verifying low flow conditions in their respective watersheds. In the Maitland watershed, MVCA uses different stations for calculating flow than the Ontario Ministry of Natural Resources (OMNR), and feels that their calculations better represent flow conditions within the watershed [40]. This lack of agreement has caused some frustration at the local level, has limited communication between the agencies, and has led to differences in opinion on the designation of drought response levels under the program.

Under the program, a Water Response Team (WRT) is to be convened to recommend actions to be taken by various stakeholders in response to low water conditions. In many watersheds, by-laws restricting nonessential water use (under Section 12 of the *Public Utilities* Act) are commonly recommended to reduce municipal water use and to protect instream surface

water flows. In the Maitland River watershed, municipalities that either own and/or operate water supply systems have adopted water restriction by-laws (e.g., towns of Goderich, Huron-Kinloss, and North Perth), but these are rarely implemented to aid in drought management. Furthermore, in a rural watershed such as the Maitland, many residents depend on private wells, and are therefore not affected by municipal water use restrictions.

The Maitland River and several of its tributaries, particularly those in the southern regions, are under level one flow conditions under the OLWR program for large periods of the year [38, 41, 56]. The reason for limited use of water restriction by-laws under the OLWR program in the Maitland is the likelihood that they would actually result in lower flows, particularly in the Middle Maitland and South Maitland rivers, since approximately 60% of annual instream flows may come from treated wastewater releases. Restricting municipal water use would reduce the amount of effluent discharged by wastewater treatment plants, thus reducing stream flow. For example, the Town of Listowel discharges its treated wastewater into the Middle Maitland River, essentially appropriating groundwater and transferring that water to the surface water system. At times, when the Maitland River watershed has demonstrated level one drought characteristics, no voluntary restrictions have been suggested because it would limit treated wastewater contributions [41].

As there are only a few surface water-taking permits within the Maitland watershed, permitted water takings are rarely restricted during low flow conditions, as it is felt that to restrict those takings would not contribute significantly to instream flows, which is the purpose of the OLWR. This disincentive for water conservation, while appropriate in the short-term, will not reduce vulnerability of the watershed community to climate change over the long term, since it does not promote conservation or sustainable water use at the municipal level, and does not address the root cause of low flow conditions. Thus, long-term adaptations should focus on reversing the impacts that land clearing, wetland filling, and extensive tile drainage have had on groundwater infiltration and contribution to instream flows.

The Ontario Low Water Response program, as it is currently conceived, may not be an ideal response to drought conditions in watersheds like the Maitland, where low baseflow, rather than high demand, is the problem [63]. Thus, it may be more useful to explore measures for increasing water infiltration to contribute to the long-term sustainability of surface water flows. Such measures may include, for example, groundwater recharge protection and wetland restoration. Conservation Ontario has suggested alternative protection strategies, which it considers to be more appropriate for low demand watersheds, to the OMNR for consideration [63].

3.3. Ability of Water Managers to Assess Current and Future Needs

A study conducted by the Lake Huron Centre for Coastal Conservation in collaboration with the University of Waterloo examined climate change implications for Lake Huron's coastal communities [36]. The project aimed to identify the level of awareness regarding climate change, information needs, and priority issues of concern, and to inventory possible adaptations. The study found that people in the conservation sector were most informed about climate change, and best able to relate how climate change might impact local water resources and use; local municipal authorities were less familiar with impacts, and more concerned about immediate issues affecting the municipality [36]. The study highlighted the need for more research on the potential impacts of climate change in the Lake Huron region, in order to facilitate decision making about adaptation, and to inspire precautionary land and water management planning at

the municipal level [36]. The short timelines associated with political terms of office, and targeting of programs to specific sectors and interest groups, make governments less likely to incorporate sustainable, long-term management of natural resources into planning [28].

MVCA technical staff has initiated an analysis of historic climate change patterns to highlight trends for the region [43, 44]. Study results were published in a local magazine, *The Rural Voice*, for general circulation to the rural and agricultural community. MVCA also has a subscription to the Canadian Institute for Climate Studies, a Victoria University-based climate modelling lab, to remain informed of the most recent climate change predictions for the Great Lakes Basin [6]. MVCA echoes findings from the Lake Huron Coastal Conservation Report, which calls for more local scale climate change research and modelling, to raise local confidence and understanding of the potential effects of climate change, and to identify and implement adaptations that could reduce vulnerability at municipal and landholder scales [6, 36].

The amount of water-related information available in the watershed has improved due to recent municipal groundwater studies (e.g., in Perth, Huron, and Bruce counties, and the Town of Minto [11, 32, 60]) and reports released by MVCA (e.g., Ecosystem Health Framework, Maitland River Hydrology Study, and a sinkhole study with Ausable-Bayfield Conservation Authority [39, 40, 55, 56, 57]). In addition to identifying wellhead protection zones for source water protection and recharge, municipal groundwater studies have attempted to catalogue existing water use using agricultural water use estimates [35], OMOE's PTTW database (a limited approach, since permitted amounts are maxima, rather than actual takings), and other relevant documentation. These studies have also attempted to estimate groundwater recharge as well as sustainable water use levels as a percentage of total annual recharge. Municipal groundwater studies noted knowledge gaps regarding the volume of available water resources [40], and the potential impacts of climate change on infiltration rates. Current understanding of the potential effects of climate change in the watershed predict fewer, more intense rain events resulting in greater surface run off, and hydrophobic soil conditions during drought, which could further increase surface water run off and the potential for flooding, and limit infiltration [25, 43]. If the frequency or duration of droughts increases, as is expected in this region under climate change, there will be a reduction in groundwater recharge and declining groundwater levels [25]. Slow recharge and falling groundwater levels may degrade the quality of groundwater. Unless groundwater studies consider the potential impacts of climate change, they may have limited potential for guiding planning in the long-term.

Despite some of the challenges that the Provincial Groundwater Monitoring Network faces, it has the potential to produce useful data, particularly if the program is funded over the long-term (i.e., past the current six year time-frame). The data produced by the network could help to determine how changes in water use and climate are influencing water resources within the province, particularly at the watershed scale. Water budgeting pilot programs, currently underway in the Credit River, Grand River, and Big Creek watersheds, could assist in assessing cumulative effects during the PTTW approval process. Initiatives such as these could lead to better estimates of future water demand and supply, better understanding of the impacts of climate change on water resources, a watershed approach to water allocation, and more sustainable water management overall [48].

3.4. Water Management Attitudes and Processes

Motivating people to think and plan in the long-term is crucial to adaptive capacity, and poses a challenge in the Maitland watershed. There is evidence of a strong perception in the

watershed that there is an abundance of groundwater and surface water (from Lake Huron) resources, which results in less interest in the cumulative effects of water takings and the potential effects of climate change on precipitation, water supplies, and consumption of water.

Recent concerns relating to water quality in the region may enhance adaptive capacity. Some water quality programs, such as the Healthy Futures program in Huron County and the Clean Water programs in Perth and Wellington counties, have provided an opportunity to cost-share implementation of riparian buffers along stream courses. The benefits of implementing these best management practices include reduced nutrient loads to streams (reducing algae growth and improving water quality during low flows), and increased infiltration of surface water (i.e., groundwater recharge). However, unstable, short-term funding for these programs remains a challenge. For example, the programs mentioned above were discontinued at the end of December, 2003. The new provincial government may "reincarnate" these programs, but confusion is created at the local and landowner levels when funding sources and implementing agencies change frequently.

The Maitland Watershed Partnerships (MWP) has the potential to increase awareness about water resource issues amongst water and terrestrial service providers. The strategic goals of the partnership clearly identify protection of water supplies and recharge areas as a priority, and highlight climate change as a concern and a reason for adopting best management practices [6, 45]. A goal of the MWP is to implement best management practices on 80 % of lands with a high potential to contaminate water, as well as marginal and fragile farmland, in the Maitland watershed over the next 10 years. High priority best management practices include nutrient management plans, buffer strips, and retirement and naturalization of marginal and fragile farmland. However, consideration of the entire farming system will likely be necessary to effectively adapt to a changing climate. For instance, changes in tillage systems may be needed to reduce erosion and improve soil moisture holding capacity; hedgerows could help conserve winter snows.

Greater awareness of watershed and sub-watershed planning has been achieved through establishment of research and partnerships within sub-basins of the Maitland watershed. The Lower Maitland Stewardship Group has undertaken development of a strategic watershed planning document, designed to identify priorities for protecting, maintaining and restoring a healthy valley system, while balancing economic and social needs [58]. Watershed groups such as this one may play a role in the protection of water resources under climate change by promoting sustainable resource use and planning for adaptation. Under the Middle Maitland Rejuvenation Project, local community members have been working together for more than 3 years to improve streamflow and water quality in the Middle Maitland River above the town of Listowel.

Local groups and organizations are working together in the Maitland watershed. For example, the Lower Maitland Stewardship Group and the Huron County Stewardship Council have jointly funded projects [8] and are both participants in the MWP [47]. Overlap between participants in the MWP and OLWR enhances adaptive capacity by augmenting local knowledge for decision making in the Maitland watershed. Groups such as the Huron Stewardship Council actively encourage their council members to participate in municipal planning processes, to ensure enhanced recognition of significant natural features [30].

In 2002, the MVCA, in partnership with Huron Stewardship Council and others, purchased a groundwater flow model to demonstrate to the public how the water cycle works, and how pollution can occur [29]. In addition to using the model in Stewardship Council activities, the

model is available for other organizations and groups to use, and has been borrowed by others in the past [8]. MVCA, in collaboration with Saugeen Conservation Authority, has a pilot project approved by OMOE to evaluate landowner response to source water protection information, and to examine factors that facilitate or constrain education of local landowners within their watersheds [55]. These types of projects play an important role in understanding local barriers to the adoption of sustainable and best management practices, and adjustments that will reduce vulnerability to climate change.

At the provincial level, there has been acknowledgement of the need for more awareness about water allocation and drought management programs, better application of these same programs, and more knowledge about the challenges of climate change for water quantity management [13]. Some efforts have been made to address these concerns at the district or regional level, but little attention has been devoted to these issues as they relate to the PTTW program as a whole [48].

4. Conclusions and Recommendations

Several characteristics of the Maitland watershed make it a useful location in which to consider the capacity of communities to adapt to climate change in the water and agriculture sectors:

- Agriculture and recreation are among the human uses of water resources in the Maitland watershed most likely to be affected by climate change. For instance, existing farms in a rain shadow area along the lakeshore may be abandoned if variability in rainfall increases. Furthermore, streamflows in the Maitland are critical for environmental systems, such as cold-water fisheries.
- The large natural variability in the hydrology of the Maitland watershed will be exacerbated by climate change, with consequences for water supply and quality. For instance, low water levels may stimulate algal growth and increase the concentration of pollutants.
- Portions of the Maitland watershed are home to many large livestock facilities, resulting in high demand for water withdrawals and production of large volumes of animal wastes. The potential exists for conflict between farms residents and seasonal, non-farm residents.

Further development of the network of partners and stakeholders currently working towards improving watershed management and local adoption of best management practices will facilitate adaptation to climate change. These partnership initiatives have built local capacity for water management and created leadership at the watershed scale. However, limitations on adaptive capacity also exist. Notably, the dominant local industries, primarily agriculture and recreation/tourism, are very sensitive to climatic variability and change.

To minimize vulnerability, the watershed community should consider adopting best management practices to reduce the potential for water quality problems related to climate change, evaluating farming systems to identify opportunities for adaptation to changing climate, assessing the potential cumulative effects of agricultural irrigation and drainage on water resources, enhancing education and awareness about climate change and appropriate adaptations for the agricultural industry, and facilitating municipal protection of local water resources and use of water conservation measures.

Based on the research conducted in this project, it is possible to nominate recommendations for consideration by stakeholders in different organizations involved in water management and land use planning in the Maitland River watershed. Because of the strong interdependencies that exist among stakeholders, these recommendations cut across levels of government and stakeholder groups. Adaptation to climate change in the Maitland River watershed will occur most successfully using a cooperative, multi-stakeholder approach that recognizes considerations such as resources available to stakeholders, the constraints imposed by institutional arrangements, and the complexity of water management as a whole.

In many respects, adaptation to climate change can be promoted through responsible water and land management. Practices such as buffer stripping, upgrading of septic systems, and protection/restoration of wetlands are good examples. These activities will influence the quality and quantity of water resources both in the present and under future climatic conditions. Programs to promote best management practices offer water quality and quantity benefits, support emerging source water protection efforts, and enhance adaptation to climate change. These programs should target implementation in locations (e.g., portions of the watershed or

specific stream segments) where investments in best management practices will have the greatest impact on water quality and/or quantity enhancement. Local and watershed organizations in the Maitland River watershed have demonstrated considerable expertise in implementing these programs, but the provincial and federal governments also have important roles to play by providing financial support. Improvements to incentive-based programs could include focusing on adaptations that increase agricultural productivity, building relationships between extension staff and farmers, funding long-term programs that recognize the time needed to design and implement changes to farming systems, and harmonizing federal and provincial funding programs.

A key challenge is facilitating the continued involvement of watershed and sub-watershed organizations in water management through financial and technical support. Organizations such as the Maitland Valley Conservation Authority and the Lower Maitland Stewardship Group have valuable local knowledge of water resources that is pertinent to a range of activities, including municipal planning, source water protection planning, and promotion of best management practices. Funds should continue to be available to such groups to support their activities. Additionally, stable financial resources for long-term activities such as groundwater monitoring are essential in groundwater-dependent, rural watersheds. Thus, financial support for the Provincial Groundwater Monitoring Network beyond the current six-year phase is essential, and would contribute not only to better water management, but also to enhanced adaptive capacity to climate change. The dependence on groundwater resources in the Maitland watershed reinforces the need for a long-term monitoring record to understand cumulative effects and assess future options, which will promote adaptation to climate variability and change.

Intensive livestock operations (ILOs) are a water quality concern in the Maitland watershed. However, there are also concerns about the quantity of water that is appropriated for watering of livestock. This has become a significant issue in neighbouring regions (e.g., Grey County). Currently, MVCA and watershed counties undertaking groundwater assessments are not able to accurately account for water takings by large livestock operations. Inadequate understanding of current water use is a constraint on decision making about water allocation both now and under future climate change. Thus, the province should require monitoring and reporting of all ground and surface water takings under the PTTW program, and require permits for livestock watering in excess of 50,000 L/day (without storage). Of course, this will require additional resources at the local level, and will be costly for permit holders. Therefore, the Province and pertinent stakeholders should explore ways of financing and facilitating enhanced monitoring.

For watersheds such as the Maitland, where surface water demand is low, the Ontario Low Water Response (OLWR) does not represent the most appropriate tool for drought management. The Maitland watershed is primarily dependent on groundwater resources, which are not currently considered in the OLWR, the province's key drought response policy. This concern has been recognized by provincial agencies and CAs [27, 40], and should be addressed as part of any changes to the provincial water allocation system. In the province’s recent White Paper [52], OLWR is mentioned only once, in the context of data collection. Much more attention to the link between OLWR and the PTTW is needed.

One clear message from the climate change literature is that water conservation measures promote adaptation. Stakeholders at all levels in the Maitland River watershed (from individual water users to senior government agencies) could do more to promote a water conscious society, for instance, by encouraging municipal water conservation through water use restrictions, public education, retrofitting programs, and long-term municipal planning for water resources. A better understanding of social, economic, and cultural barriers to water conservation is needed.

In an effort to protect both the quality and quantity of source waters, CAs and municipalities soon will be expected to take on new responsibilities [52]. Watershed-based source water protection, as it is currently conceptualized, has significant implications for the financial and technical capacity of local organizations. Source water protection, to the extent that it will integrate water quantity and quality management, presents an opportunity for enhancing adaptation to climatic variability and change. By virtue of their proposed role, conservation authorities should become advocates for the inclusion of climate change considerations in source protection plans.

Finally, agencies, organizations, and individuals undertaking climate change research and education should have regard for the needs of watershed and local decision-makers. Many day-to-day decisions of municipalities and other local agencies have long-term implications for adaptation to climate change. Information that is more specifically targeted to these decision-makers, and developed with their participation, is likely to have greater influence on their decisions and hence on their overall capacity to adapt to a changing climate.

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