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Strategic Large-Basin Management for Multiple Benefits:

Submission to the Manitoba Clean Environment Commission

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Written by Karla Zubrycki, Dimple Roy, Henry David Venema and Richard Grosshans.

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1.0 Executive Summary

This paper makes the case for strategic basin management in the Lake Winnipeg/Nelson River basins to ensure that decisions related to lake regulation and related power management are made in an integrated context.

Compared to the other large lakes in the world, Lake Winnipeg's ability to store water is the smallest relative to its basin size, and the pressures from the surrounding watershed are arguably amongst the largest based on the sheer amount of land draining into it. The lake's volume relative to the size of its basin is the smallest of the world's large lakes. In an index we created to compare lake volume to basin size, the next smallest measurement is that of Great Slave Lake, which is still 7.5 times greater than the index number for Lake Winnipeg. Lake Superior's volume:basin index measurement is 329 times greater. The low volume relative to basin size means that pressures on the lake are often intensified.

As a result, Lake Winnipeg is particularly vulnerable to upstream influences. The basin and lake are naturally prone to drought, flooding and nutrient loading (especially via the nutrient-rich Red River), and climate change is expected to exacerbate these concerns in much of the basin. Therefore, this report focuses on three main topics that the International Institute for Sustainable Development (IISD) asserts are important to consider when making decisions concerning Lake Winnipeg: climate change, nutrient loading and the multiple benefits value of large-basin management planning. We suggest that the concerns of climate change (including increased floods and droughts) and nutrient loading can be addressed by managing the entire basin to produce ecosystem services, benefits provided by ecosystems, that include not only power generation but also an array of other benefits such as "climate regulation, water regulation, natural hazard regulation, energy, freshwater nutrient cycling, water purification and waste treatment, disease regulation, primary production, fisheries and recreation, and ecotourism" (Roy, Barr, & Venema, 2011, p. 2).

Using the example of water storage in wetlands and other storage areas, we argue that such management approaches help in attaining multiple benefits and can be used to balance climatic, land-use and other human-use pressures on land and water.

For example, many experts consider wetland conservation and restoration to be one management method that can attain many benefits. Numerous studies (Pomeroy et al., 2014; Westbrook et al., 2011; Yang et al., 2008) show that wetland drainage has caused increased flooding. Evidence is accumulating that management of wetlands and other ecosystems generates multiple benefits. Baker, Griffis and Ochsner (2012) recognize the opportunity to design solutions that produce multiple benefits, and suggest that water storage in the U.S. Midwest could facilitate supplemental irrigation while also reducing flooding and capturing nutrients, thereby helping to address eutrophication problems in the Gulf of Mexico. This distributed storage approach involves storing water on the land in a dispersed manner. The purpose is not only to hold water but also to bring multiple benefits.

These are seen as cost-effective management options in light of the multiple valuable benefits they provide. In their benefit-cost analysis of three different water storage options (re-graded ditches, filter fields/ponds and back-flooded dams), Dion and McCandless (2014) found that all three management options offer benefits including avoided flooding through water storage, reduced nutrient loading and carbon credits, with benefit:cost ratios ranging from 128 to 371 per cent.

Compiling these studies, we suggest that upstream land management approaches such as wetlands and designed water storage provide multiple benefits including flood and drought mitigation, nutrient capture, habitat provision, economic opportunities, and carbon sequestration, and make these approaches worthwhile investments in the context of large-basin management and hydropower generation.

We make the case that Manitoba and the entire Lake Winnipeg/Nelson River basins will be able to adapt to the challenges of climate change, flood, drought and nutrient loading by adopting a whole-basin management approach while considering how the lake itself is regulated. The state of the lake and the benefits it provides (such as power generation) are affected not only by lake regulation, but also by actions on and management of upstream land and water. We profile other large basins in which management for ecosystem services, including the generation of hydroelectric power, is being pursued. In particular, the Columbia River and Murray-Darling River basins are useful case studies in transboundary management to produce multiple benefits.

Therefore, our overarching recommendation is that there is need for a framework for basin-wide management, and that ecosystem services should be an integral part of its design. The Lake Friendly Accord and Lake Friendly Stewards Alliance may already be building this groundwork. We further recommend that an entity be created to help guide basin-wide management, or that an already existing entity be provided support and resources for this mandate.

Our other recommendations link closely to the need for large-basin management of the Lake Winnipeg/Nelson River basins. As part of more integrated binational management, we make the following additional recommendations:

- Consider the land as infrastructure.
- Invest in upstream management, including storage to influence Lake Winnipeg levels and power generation.
- Use financial mechanisms, such as water markets, to generate ecosystem services.
- Manage upstream for nutrient capture.
- Manage upstream for climate change adaptation and natural hazard buffering.

Topics raised repeatedly during the Lake Winnipeg regulation scoping session included climate change and eutrophication (Manitoba Clean Environment Commission, 2014). The subsequent process has seen these concerns mentioned repeatedly during consultations. Clearly, these concerns are top-of-mind for stakeholders. We urge that large-basin management for ecosystem services be considered alongside lake regulation in order to produce the most comprehensive planning and sustainable outcomes.

2.0 Introduction

In lakes and rivers throughout the world, we're seeing issues pertaining to water quality, quantity and access for human and environmental needs. A desired way of managing these systems strategically is through integrated, whole-basin management, considering all the different benefits that stem from healthy ecosystems and collectively prioritizing these as a watershed community. Globally recognized approaches such as integrated water resources management (IWRM) are being used to balance complementary and competing needs and prioritize these for ecological, economic and equitable use. This paper makes the case for strategic basin management in the Lake Winnipeg/Nelson River basins to ensure that decisions related to lake regulation and related power management are made in a comprehensive context.

As one of the world's largest freshwater lakes, Lake Winnipeg stands out as one of the most prominent geographical features on a map of Manitoba. It also has a major influence on the province's economy by serving as the third-largest hydroelectric reservoir in the world (Government of Manitoba, 2015), supporting a major commercial fishery and attracting tourists. Moreover, it contributes to the well-being of Manitobans, not only by generating revenues through these economic benefits, but also by offering recreation, existing as a cultural point of pride and being home to roughly 23,000 people along its shoreline. Environmentally, it also offers a critical habitat to many species, including migratory birds.

Given the environmental importance of Lake Winnipeg and its influence over Manitobans, it is important to manage human activities, both in the lake and in the upstream watershed, so that these benefits continue to be enjoyed. Unfortunately, Lake Winnipeg has seen nutrient loads increase in the past decades, to the point that it was named "Most Threatened Lake of the Year" in 2013 by the Global Nature Fund (Water Canada, 2013).

In preparing this submission to the Manitoba Clean Environment Commission (CEC), the International Institute for Sustainable Development (IISD) has considered the ongoing environmental pressures the lake faces in the context of its socioeconomic importance. This report focuses on three main topics that IISD believes are important to consider when making decisions concerning Lake Winnipeg: climate change, nutrient loading and the value of large-basin management planning.

The geography of the Lake Winnipeg Basin is unique, with a remarkably large basin size (nearly 1 million square kilometres) (see Figure 1) compared to its surface area (23,750 square kilometres) and volume (284 cubic kilometres) (Government of Manitoba, 2015). Compared to the other large lakes in the world, Lake Winnipeg's ability to store water is the smallest relative to its basin size, and the pressures from the surrounding watershed are arguably amongst the largest based on the sheer amount of land draining into it. Lake Winnipeg also has only one outflow, through the Nelson River, which adds further challenges to regulating lake levels.[1] Most hydroelectric development is focused downstream of Lake Winnipeg.

1 Though normally under natural conditions a lake will only have one outflow.

FIGURE 1. LAKE WINNIPEG WATERSHED.

Source: IISD

The fact that the Lake Winnipeg watershed is nearly 40 times the surface area of the lake itself is an often cited and useful statistic (e.g., Environment Canada and Manitoba Water Stewardship, 2011; Lake Friendly, 2014; Lake Winnipeg Stewardship Board, 2006). This represents the largest drainage-surface area ratio of the world's largest lakes (see Figure 2).

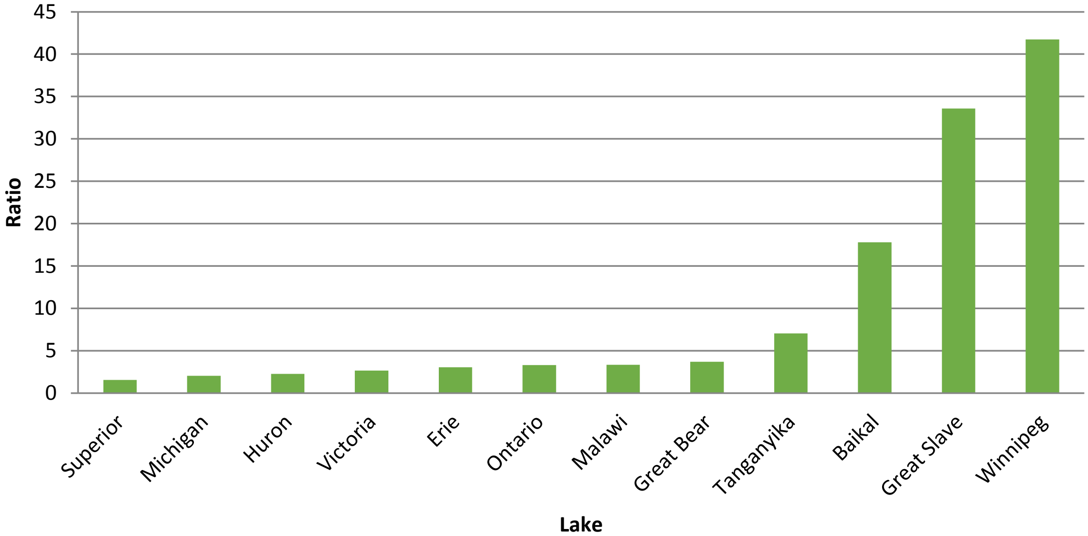

FIGURE 2. BASIN AREA/LAKE SURFACE AREA OF THE WORLD'S LARGEST FRESHWATER LAKES.

Source: IISD

A lesser known statistic that presents an even more startling illustration of the pressures exerted by the surrounding basin is found by considering Lake Winnipeg's volume relative to the size of its basin, something we have called the "volume:basin index," calculated by dividing the volume (cubic kilometres) into the basin area (square kilometres). Simply put, the combination of a shallow lake and vast basin results in the storage capacity of Lake Winnipeg being very small compared to that of other large lakes (see Figure 3). The volume:basin index for Lake Winnipeg is 0.000288. The next smallest is that of Great Slave Lake, which is still 7.5 times greater, at 0.002152. Lake Superior's is 329 times greater.

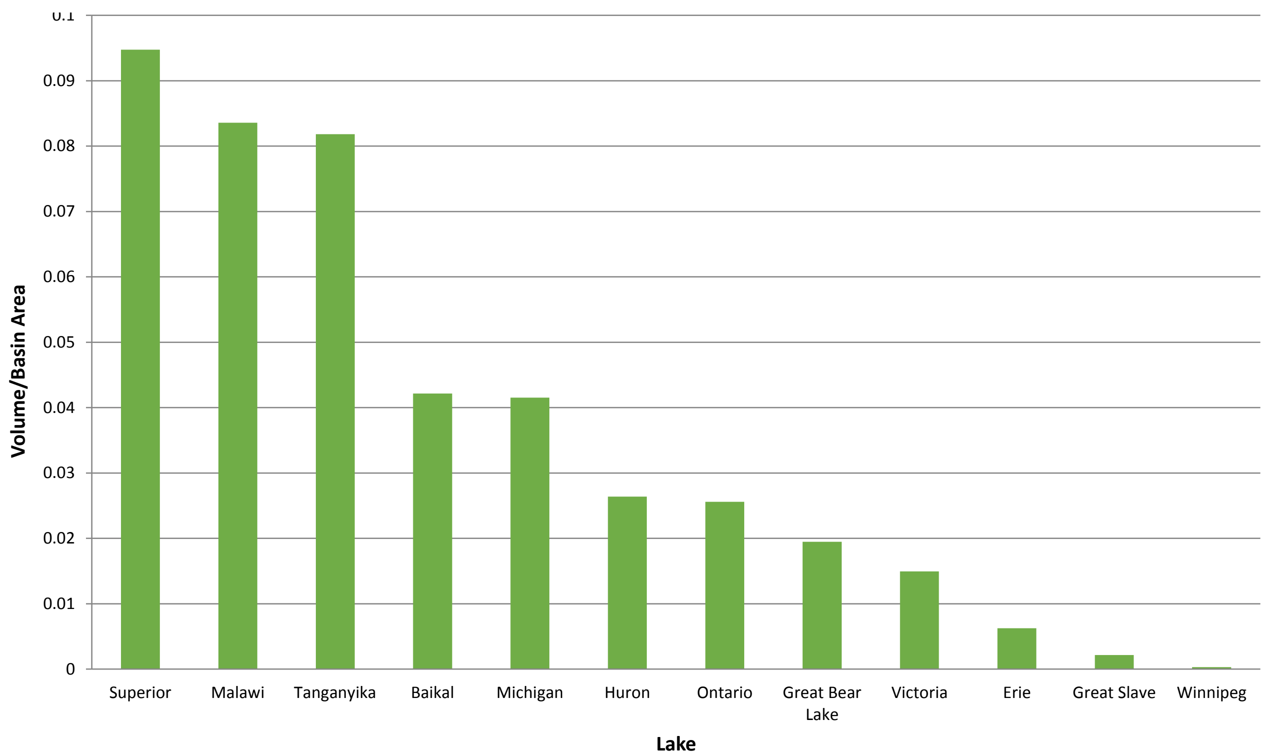

FIGURE 3. VOLUME/BASIN AREA INDEX OF THE WORLD'S LARGEST LAKES.

Source: IISD

The low volume relative to basin size may mean that pressures on the lake are intensified. For example, high nutrient loads coming from upstream can increase the concentrations of phosphorus and nitrogen in Lake Winnipeg more quickly than they would in a deeper lake with greater volume. Similarly, high water flows and flooding in the basin can relatively quickly increase lake levels; with nearly 1 million square kilometres flowing toward it, and only one outflow through the Nelson River, it is not uncommon for Lake Winnipeg to reach 715 feet above sea level, the level at which the interim Water Power Act requires Manitoba Hydro to release maximum discharge at Jenpeg, a Manitoba Hydro generating station on the Nelson River that controls and regulates outflow from Lake Winnipeg (Manitoba Hydro, n.d.).

This report summarizes information showing how climate change may alter water flow and nutrient loading pressures in the future. However, we make the case that Manitoba will be able to adapt to these changes only by considering how the lake itself is regulated *in combination with* how its drainage basin is managed, as the state of the lake and the benefits it provides are affected not only by lake regulation but also by actions and management on upstream land and water. Therefore, we suggest that management must also include upstream actions if the goal is to achieve the best results for the health of Lake Winnipeg, as well as the economies, people and ecosystems that benefit directly or indirectly from it. With such a large basin area relative to lake size and volume, there is opportunity to manage water quantity and quality upstream, addressing current concerns and proactively preparing for challenges such as climate change, before the water ever reaches the lake itself.

3.0 Climate Change

The hydrology of the Lake Winnipeg Basin naturally makes it vulnerable to floods and droughts. Part of the watershed falls in what is known as "Palliser's Triangle," an area that includes parts of Alberta, Saskatchewan and Manitoba. This area was deemed unfit for agriculture by explorer John Palliser, who remarked in the 19th century that the region's aridity would make farming difficult (see Figure 4). Another portion of the watershed is in the highly flood-prone Red River Valley, where flat land and heavy spring runoff have led to devastating floods.

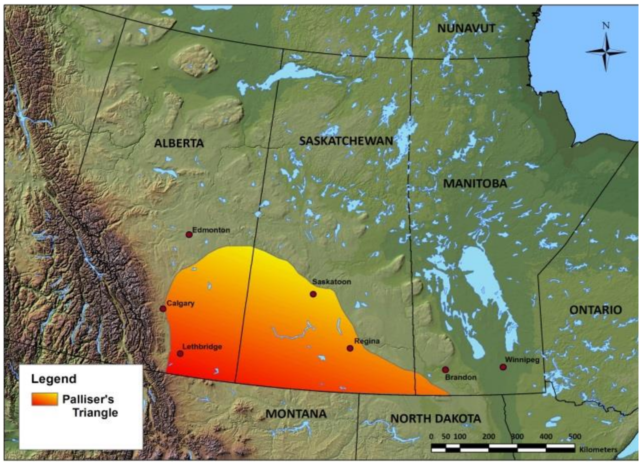

FIGURE 4. PALLISER'S TRIANGLE

Source: IISD

This natural vulnerability makes the need to consider climate change more pressing. It is anticipated that flood and drought extremes may increase with climate change in many parts of the basin. Sauchyn and Kulshreshtha (2008) identify drought and water scarcity as "the most serious climate risk" faced on the Canadian prairies. Likewise, the most recent federal government report on climate change comments that "the southern Prairies were identified in particular as having a higher likelihood of drought conditions in the future" (Warren & Lemmen, 2014, p. 36). Regional climate models predict decreases in summer and fall precipitation, decreased summer and fall streamflow, and higher frequency and duration of droughts (Bonsal et al., 2012; Mazumder et al., 2013; Sushama et al., 2010). Studies on tributaries of the Saskatchewan River, the water of which ultimately enters Lake Winnipeg, indicate higher spring flows and lower summer flows (Forbes et al., 2011; Kienzle et al., 2012; Lapp et al., 2009).

At the same time, climate models also suggest that the Lake Winnipeg Basin may see more frequent and extreme flooding in the future (Sauchyn & Kulshreshtha, 2008; Stantec, 2012). In their modelling of sub-catchments of the Red and Assiniboine rivers, Shrestha et al. (2011) found that changes may include higher overall runoff and increases in peak discharge intensities. Warren and Lemmen (2014) write that "Rare extreme precipitation events are currently projected to become about twice as frequent by mid-century over most of Canada" (p. 9).

Increased droughts and floods, as well as greater hydrologic extremes in general, have potential implications for hydroelectric operations. Regarding decreased flows and increased drought risk, Sauchyn and Kulshreshtha (2008) comment that "Approximately 95% of the electricity generated in Manitoba comes from renewable water energy… Future hydro generation will be impacted by decreasing water flows from the western portion of the Prairies due to glacial ice decline…and lower snow accumulations" (312).

In the context of Lake Winnipeg regulation, the prospect of more frequent and lengthy droughts represents a vulnerability for Manitoba Hydro operations. The residence time of water in Lake Winnipeg (i.e., the amount of time water spends in the lake) is low relative to other large lakes: on average it is three to five years, compared to, for example, 191 years for Lake Superior (Environment Canada and Manitoba Water Stewardship, 2011). Low residence times mean that the effects of drought can be felt fairly quickly in the lake, with operational and economic implications for Manitoba Hydro. Simply put, if water levels decline, less electricity is generated. Manitoba Hydro has experienced drought numerous times throughout its history. The 1989 drought led to a CAD$28 million loss, while the 2002–2003 drought led to a CAD$436 million loss (Simard & Joyce, 2005). In 2007, Manitoba Hydro calculated that a five-year drought could result in decreased electricity generation of 31,952 gigawatt hours and cost roughly between CAD$2.2 billion (conservative estimate) and CAD$3.5 billion (Manitoba Hydro, 2007).

Conversely, extreme high-water flows would require Manitoba Hydro to run outflows from Lake Winnipeg at full capacity to keep lake levels lower. According to the Interim Water Power Act Licence, Manitoba Hydro is required to release as much water as possible at Jenpeg when levels are above 715 feet above sea level. Hesslein (unpublished) writes that Lake Winnipeg regulation appears to have actually helped reduce peak levels in Lake Winnipeg because Jenpeg has increased overall flow capacity. In this regard, lake level regulation may in some respects be viewed as beneficial in times of high lake water levels, though the potential effects of heavy outflows on downstream communities should be acknowledged and considered.

In addition, it is worth considering a scenario where all or part of the Lake Winnipeg watershed experiences floods and drought in quick succession, as occurred to some degree in 2011, when an unusually wet spring was followed by drought in summer (CBC, 2011; Vanderclippe, 2011). This situation underscores the unpredictable nature of hydrology and meteorology, and makes it evident that the hydro sector in the Lake Winnipeg watershed must plan proactively for both floods and droughts. Warren and Lemmen (2014) write of expected increases in winter flows and decreases in summer flows:

> Projected climate impacts almost always involve major changes in the distribution of flow throughout the year, which presents challenges to most current dams and reservoir management. For instance, reservoirs are currently kept very low during winter in order to store melt water in spring. With increasing winter flows and earlier and lower spring flows, a new strategy could involve storing water throughout the winter as well, to help offset the impacts of lower summer flows. (p. 87)

While flood and drought extremes present vulnerabilities for hydroelectric generation, hydro is one of the sectors most engaged in planning and preparing to cope with such events (Warren & Lemmen, 2014). Some examples of how watershed managers, including hydro companies, are using adaptive management to cope with extreme water levels are provided in section 5.

4.0 Nutrient Loading to Lake Winnipeg

Lake Winnipeg is already under considerable stress from excessive nutrient loading, and climate change may further exacerbate this problem. With a basin of nearly 1 million square kilometres, the opportunities for nutrients to enter waterways eventually flowing into Lake Winnipeg are substantial. Sources of phosphorus are varied and include point sources (e.g., wastewater, industry) and non-point (e.g., landscape) sources. In Manitoba, non-point sources from the land amount to an estimated 67 per cent of loading from within the province (see Figure 5), or 32 per cent of total phosphorus loading to Lake Winnipeg from the entire basin (Oborne & Venema, 2007). The high portion of diffuse sources is an indication that in order to reach the targeted 50 per cent reduction in phosphorus loading to Lake Winnipeg (Province of Manitoba, 2011), it will be essential to find innovative and cost-effective ways to reduce nutrient loading from the landscape.

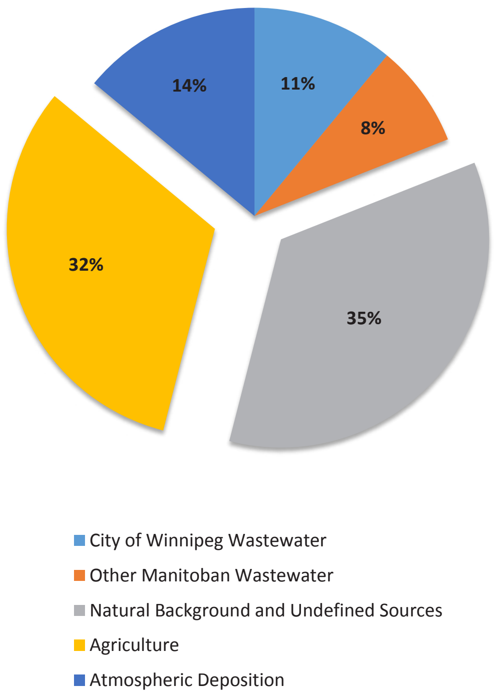

FIGURE 5. MANITOBAN PHOSPHORUS SOURCES TO LAKE WINNIPEG

Source: Lake Winnipeg Stewardship Board 2006

4.1 Non-Point Nutrient Loading

While algal blooms in Lake Winnipeg are the most obvious indicator of excessive nutrient loading in the lake, the problem itself originates upstream. As noted above, roughly two-thirds of phosphorus loading from within Manitoba is from non-point sources. Recent research has clarified that a major factor in bringing nutrients from the watershed and into Lake Winnipeg is flooding. The large extent to which upstream flooding contributes to nutrient loading in Lake Winnipeg was articulated by McCullough et al. (2012), who found that increased runoff and flooding in the mid-1990s, particularly in the nutrient-rich Red River Basin, markedly increased phosphorus inputs. Phosphorus enters waterways during flooding both by the leaching of soluble phosphorus from inundated soils as well as through particulates. The authors modelled the effects of high runoff and frequent flood events in the Red River Basin and found that high runoff experienced in the Red River Basin beginning in the mid-1990s could be the cause of as much as a 32 per cent increase in phosphorus concentration in Lake Winnipeg. The model suggested that human-related sources, in contrast, might have caused only 14 per cent. The authors concluded, "It required both increased loading to the land and higher runoff to produce the observed increase in TP in the lake." (p. 95)

Wetlands drainage is one example of upstream management actions that affect both floods and nutrient loading. This study can be considered in the context of research by Pomeroy et al. (2014), who found that drainage of wetlands in the Smith Creek Basin, Saskatchewan, increased both peak flows (i.e., the highest river level reached during spring melt and floods) and annual flows. Their model demonstrated how streamflow volume and peak flows have "remarkably strong sensitivity to wetland drainage" (p. 52). In the case of the 2011 flood, had the wetlands covered the same area they did in 1958, the flood peak would have been reduced by 32 per cent and the annual streamflow volume by 29 per cent. Moreover, if wetlands had been completely drained in the basin, the 2011 flood peak would have increased by 78 per cent. These findings have strong implications for nutrient loading: exacerbated flood peaks offer more opportunity for nutrients to enter waterways, both in dissolved form and in sediments. Even in normal to dry years, one could likely expect nutrient loading reductions were wetlands to cover the area they did in 1958; the model showed that this scenario would decrease peak discharges by 35 to 70 per cent in moderate- to low-flow years. While this research did not investigate nutrient loading, another study on the Smith Creek Basin did (Westbrook et al., 2011). One purpose of the study, conducted during spring runoff in 2009, was to "determine the extent to which stream water quality is influenced by wetland drainage" (p. 6). The authors found increased phosphorus export in sub-basins with greater wetland drainage, with 100 per cent of such sub-basins exceeding provincial total phosphorus guidelines, compared to 63 per cent for sub-basins with low wetland drainage. The study also noted higher discharge in more highly drained sub-basins, the authors remarking that these findings aligned with other evidence that "wetland drainage increases effective contributing area and stream discharge" (Saskatchewan Watershed Authority, 2008). However, the science is not yet certain. Ehsanzadeh, van der Camp and Spence (2014) suggest changes in watershed storage have had minimal effects on the hydrology of major inflows to Lake Winnipeg.

Studies have emphasized the negative environmental impacts and related economic losses based on floods and nutrient loading; watershed modelling, for example, has demonstrated the ecological (and economic[2]) price paid for wetland loss in Manitoba in terms of increased peak flows and nutrient loading. Yang et al. (2008) studied the Broughton's Creek watershed in southwestern Manitoba, where 70 per cent of wetlands were degraded or drained between 1968 and 2005. The hydrologic model used found that this loss resulted in an "18 per cent increase in peak flow following rainfall," a "30 per cent increase in water flow" and a "31 per cent increase in nitrogen and phosphorus loading from the watershed" (Ducks Unlimited, 2008, p. 2). The study also extrapolated the model to the Little Saskatchewan River watershed, which covers a large portion of southwestern Manitoba and showed that wetland loss could contribute 6 per cent of total annual phosphorus loads to Lake Winnipeg from human-related Manitoban sources.

The 2015 CEC process is not the first time the Commission has considered nutrient loading to Lake Winnipeg and the various watershed pathways. In 2007, IISD (Oborne and Venema, 2007) wrote a report relating to the hog production industry review and commented on the significant role played by hydrology. The authors emphasize the importance of considering the effects of upstream management on downstream waterways:

> The ecological effects of altering headwater streams (and wetlands) in a watershed through enhanced drainage and increased peak flows are magnified by land uses that also increase runoff and nutrient loads to streams. The cumulative effects of these alterations typically result in increased downstream eutrophication and other negative ecological impacts. (p. 31)

Research into flooding and nutrient loading is also relevant to climate change concerns related to Lake Winnipeg watershed management. Wetlands store carbon, and their loss releases it. As discussed in section 3, climate change is expected to be a driver of increased flooding and nutrient loading to Lake Winnipeg. The case study on the Little Saskatchewan Watershed helps illustrate this connection; wetland loss may have released up to 5 million tonnes of carbon since 1968, "equivalent to the emissions of 169,000 cars for 20 years" (Ducks Unlimited, 2008, p. 3). The loss of wetlands and resulting loss of their benefits (carbon storage, nutrient capture and water storage) contribute to a cycle wherein climate change impacts increase, hydrologic activity intensifies and there are potentially higher peak flows, which subsequently drive further nutrients into Lake Winnipeg.

[2] While the economic benefits of wetlands are not the focus of this report, the estimated CAD$430 million lost in ecosystem services in the Little Saskatchewan watershed in the study period, and CAD$15 million in 2005 alone, provides a strong argument to conserve and restore wetlands.

4.2 Nutrient Loading and Climate Change Linkages

The two pressures on Lake Winnipeg that have been identified in this paper, climate change and nutrient loading, provide an even more persuasive argument for action when their interactions are considered. Climate change could increase nutrient loading to Lake Winnipeg, as well as create conditions for blue-green algal blooms.

In the watershed, increased flooding could carry more nutrients into the lake. Shrestha et al. (2011) note the following:

> Climate-inducted hydrologic changes may also bring about…an increase in flood hazards due to increases in peak snowmelt discharge. This may be especially important given the flood history of the Red and Assiniboine Rivers. Moreover, the above noted hydrologic changes can also influence nutrient transport processes – a major concern…for Lake Winnipeg. (p. 10)

Meanwhile, droughts could lead to increased soil erosion from agricultural lands (Sauchyn & Kulshreshtha, 2008); without management approaches such as vegetative buffers, more sediments and nutrients could enter waterways leading to Lake Winnipeg.

In addition, the proportions of water flowing into the lake from different rivers could change, altering the water quality. Diminished glacier melt may result in lower flows from the Saskatchewan River, which runs into Lake Winnipeg from the west. Water from the Saskatchewan River is relatively low in nutrients,[3] contributing 4 per cent of phosphorus loading and 8 per cent of nitrogen loading (Lake Winnipeg Stewardship Board, 2006). While inflow from this river will decrease, flows from the nutrient-rich Red River could increase due to changes in precipitation patterns. The Lake Winnipeg Research Consortium (2008) reports, "If Red River flow variability increases with global warming, as predicted by regional climate models, it will become increasingly important to strictly manage phosphorus and water in the Red River basin if we hope to achieve improvement in Lake Winnipeg water quality" (p. 6).

Within the lake itself, a warmer climate might also exacerbate algal blooms by producing conditions favourable to blue-green algae, as warmer temperatures are conducive to algal growth, including blue-green algae (Sauchyn & Kulshreshtha, 2008; Environment Canada and Manitoba Water Stewardship, 2011). Sauchyn and Kulshreshtha (2008) report that "The size of massive algae blooms in Lake Winnipeg correlate with higher summer temperatures" (p. 291). The latest report on the state of Lake Winnipeg remarks, "The nature and extent of eutrophication and associated effects on Lake Winnipeg may be affected by rising air temperatures" (Environment Canada and Manitoba Water Stewardship, 2011, p. 158). Climate models suggest mid-summer surface water temperatures may increase by 1.9°C to 2.5°C by 2050, and by a further 0.5°C to 2°C by the end of the century, though deeper water might not be heated to this extent.

4.3 Integrated Approaches to Address Non-Point Nutrient Loading

The interconnected challenges of excessive nutrient loading, flooding and climate change beg for solutions that are complementary and, ideally, help to address all three problems. Baker, Griffis and Ochsner (2012) recognize the opportunity to design solutions that produce multiple benefits. They propose that construction of ponds and restoration of wetlands in the U.S. Midwest could be viewed as a form of water storage for supplemental agricultural irrigation and enhancement of food production that also reduces flooding, which has increased in recent decades (as it

[3] By comparison, the Red River contributes 54 per cent of phosphorus and 30 per cent of nitrogen, and the Winnipeg River contributes 11 per cent of phosphorus and 18 per cent of nitrogen (Lake Winnipeg Stewardship Board, 2006).

has in Manitoba). Wetlands have the added benefit of capturing nutrients, thereby helping to address eutrophication problems in the Gulf of Mexico. This proposed approach is an example of distributed storage, where a large amount of water is stored on the land in a dispersed manner; no one storage area is necessarily large. The purpose of distributed storage is not simply to hold water; rather, it is meant to bring multiple benefits.

There are already some examples of distributed storage approaches producing multiple benefits in the Lake Winnipeg Basin. Many of these solutions relate to what is being called "keeping water on the land" (Lake Winnipeg Foundation, 2013; Manitoba Conservation Districts Association, 2013).

One of the early innovators in this area was South Tobacco Creek, a watershed located in south-central Manitoba, where landowners constructed small dams to help manage water flows. Tiessen et al. (2011) studied the impacts of two South Tobacco Creek dams on flows, sediments, nitrogen and phosphorus, and found that peak flows were reduced and water quality was improved (see Table 1). These changes would benefit downstream waterways, including Lake Winnipeg. In a climate change context, these dams can also be viewed as buffers to help absorb increased hydrologic shocks involving spring snow melts and heavy rainfalls.

TABLE 1. REDUCTIONS IN PEAK FLOW, SEDIMENT LOAD, TOTAL NITROGEN AND TOTAL PHOSPHORUS AT TWO SOUTH TOBACCO CREEK SITES.

	STEPPLER DAM	MADILL DAM
Average reduction in peak flow during snowmelt	72%	44%
Annual sediment load reduction	77%	66%
Annual total nitrogen load reduction	15%	20%
Annual total phosphorus load reduction	12%	9%

Source: Tiessen et al. (2011)

South Tobacco Creek is on the hilly Manitoba escarpment and, as such, is not typical of much of southern Manitoba's landscape. However, the North Ottawa Impoundment Project in the Bois de Sioux watershed in Minnesota, which more closely resembles the typical Manitoba prairie landscape, also offers evidence for reservoirs benefitting water flows and quality. The system of dikes, gates and subimpoundments over 1,920 acres is designed to provide 19,735,700 cubic metres of storage and is expected to reduce peak flows downstream by an estimated 5 per cent, thereby helping to address frequent flooding problems while also reducing nutrient and sediment loading (Bois de Sioux Watershed District, 2012). Once the interior dike system is completed in the summer of 2015, water will be moved between interior compartments to control depths, timing of water retention to allow for nutrient capture by sediments and plants, and drainage of compartments to harvest cattails and other plant species. The North Ottawa impoundment receives nutrient-rich water from a drainage area of 186 square kilometres. Preliminary estimates indicate harvesting 600 acres of cattail could capture and remove 9,000 pounds of phosphorus, which is equivalent to the average annual load of phosphorus from runoff received from the drainage area. Detailed research on the North Ottawa impoundment and the potential for reducing nutrient loading to Lake Winnipeg will begin in the summer of 2015 (Jeff Lewis, Red River Basin Commission, personal communication, 2015).

The benefits of various water management approaches, including reservoirs similar to South Tobacco Creek and the North Ottawa project, have been studied by Manitoban researchers (e.g., Ali et al., 2013; Dion & McCandless, 2014; Lobb & Randall, 2012). In their benefit-cost analysis of three different water storage options (re-graded ditches, filter fields/ponds and back-flooded dams), Dion and McCandless (2014) found all three options to offer benefits, including avoided flooding through water storage, reduced nutrient loading and carbon credits, with benefit:cost ratios ranging from 128 to 371 per cent (see Table 2). Back-flooded dams, most similar to South Tobacco Creek and the North Ottawa project, were found to have the highest benefit:cost ratio. The benefits and costs considered in calculations are listed in Table 3.

TABLE 2. BENEFIT:COST RATIOS OF THREE DISTRIBUTED STORAGE APPROACHES

Back-flooded dams	371%
Re-graded ditches	194%
Filter fields/ponds	128%

Source: Dion and McCandless (2014)

Another solution of interest is the conservation and restoration of wetlands, a more traditional approach supported by research from many studies in watersheds around the world that indicate flood, nutrient capture and other benefits (e.g., Brander, Brouwer, & Wagtendonk, 2013; Richardson et al., 2011; Zhang & Song, 2014). In the Lake Winnipeg context, Yang et al. (2008) found that restoring wetlands in the Little Saskatchewan watershed in southeastern Manitoba could reduce phosphorus loading by as much as 34.1 per cent, nitrogen by 18.9 per cent and peak discharges by 23.4 per cent, depending on the percentage of wetlands restored.

TABLE 3. BENEFITS AND COSTS OF DISTRIBUTED WATER STORAGE

BENEFITS	COSTS
Avoided drought	Up-front capital costs
New wetland habitat	Operating costs
Production of cattails	Lost farmland (opportunity cost)
Carbon credits	
Reduced eutrophication	
Avoided flooding costs	

Source: Dion and McCandless (2014)

The strategic placement of distributed storage throughout the basin could help watershed managers realize some part of the 50 per cent phosphorus reduction urged by Bunting et al. (2011). In order to prevent a major change in the Lake Winnipeg algal population, the authors recommend reductions in phosphorus inputs to the lake (i.e., from upstream sources), concluding that internal lake mechanisms such as nutrient re-suspension are not a major factor in eutrophication. Hesslein (2015) concludes that lake regulation would have minimal effects on phosphorus in Lake Winnipeg—likely less than 2.5 per cent—and remarks that this amount is "very small compared to the changes in P concentration caused by inflow variations and insignificant in the overall nutrient management of the lake" (p. 11). Therefore, if nutrient inflows to the lake were reduced, in-lake nutrient levels should respond and decline in a reasonable time frame.

Based on this report and other mounting scientific evidence, the province of Manitoba has targeted a 50 per cent reduction in phosphorus loading to Lake Winnipeg (Province of Manitoba, 2011). Undertakings such as the North Ottawa project and South Tobacco Creek, discussed above, provide compelling proof that landscape management efforts such as distributed storage can be a cost-effective pathway toward watershed management for the multiple benefits of nutrient capture and climate buffering.

5.0 Large-Basin Management Planning

The concerns discussed in this paper—nutrient loading, floods, drought and climate change—share a common characteristic in that they all manifest on a watershed basis. These concerns do not respect political and jurisdictional boundaries such as federal, state or provincial lines. Therefore, in order to effectively address these challenges in the Lake Winnipeg Basin, management would best be done through a basin-wide framework that engages the four states and four provinces whose lands fall within the basin, along with the many other governments, sectors and stakeholders who rely on the basin's natural resources.

Increasingly, frameworks for basin management are incorporating a concept known as ecosystem management to optimize the management and delivery of ecosystem services. Popularized by the global Millennium Ecosystem Assessment conducted and reported by global scientists across the world in the 2000s, ecosystem services are "the direct and indirect contributions of ecosystems to human well-being…that support directly or indirectly our survival and quality of life" (Biodiversity Information System for Europe, n.d.). They include "*provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and *spiritual benefits*; and supporting services such as soil formation, photosynthesis, and nutrient cycling" (Millennium Ecosystem Assessment 2005, p.v). In the ecosystem services framework, hydroelectricity generation is one of many provisioning services.

The incorporation of ecosystem services into watershed planning is relatively new, with watersheds around the world struggling to value and incorporate environmental and social benefits of functioning watersheds beyond the traditional focuses of power generation, irrigation and large-scale projects for flood control (Raje & Mujumdar, 2010; Soito & Freitas, 2011). However, as the need for adaptive management in the face of climate change becomes more evident, such attempts are becoming increasingly common.

This section will outline how basins around the world are increasingly moving toward large-basin management planning. With the provincial government of Manitoba already setting up a cooperative framework to help address basin issues, the Lake Friendly Accord, there may be an emerging opportunity for large-basin management while planning management of the Lake Winnipeg and Nelson River Basins. We present the following case studies to consider for such an approach.

5.1 Columbia River Basin

One strong example of large-basin management planning is the Columbia River Basin (see Figure 6). Management approaches here recognize the multiple benefits of the basin and its natural resources, including hydro power generation, tourism, fishing, forestry, mining and agriculture. Moreover, management has attempted to balance development and ecosystem needs, which has led to the use of innovative policy instruments.

FIGURE 6. COLUMBIA RIVER BASIN

Source: Musser (2008)

The Columbia River Basin has many characteristics similar to those of the Lake Winnipeg Basin. At roughly 670,000 square kilometres, it is multi-jurisdictional, including the states of Oregon, Idaho, Washington and Montana, as well as the province of British Columbia. With more than 370 hydroelectric dams, its energy potential is highly developed. Like the Lake Winnipeg Basin, it is prone to floods and droughts (Bonneville Power Administration and the U.S. Army Corps of Engineers, 2013; Gedalof et al., 2004). Human activities have also greatly altered the watershed, resulting in changes in water quality, water quantity and wildlife habitat.

In the U.S. portion of the basin, power generation and ecosystem health, particularly fish habitat, are considered in tandem. In 1980, the Pacific Northwest Electric Power Planning and Conservation Act was created to balance energy demands with ecosystem needs (Leonard et al., 2015). The Act created the interstate Northwest Power and Conservation Council, charged with "planning, policy-making and reviewing" (p. 89) and expressly required it to consider activities on a basin-wide scale. The Act stated that activities should "to the greatest extent possible… be designed to deal with that river and its tributaries as a system" (Pacific Northwest Electric Power Planning and Conservation Act, §4(h)(1)(A), 94 Stat. 2708).

The Act also requires the Council to create both a fish and wildlife program and a power plan, thereby obliging it to consider these competing uses. The funding of conservation activities is also tied to power generation, as the fish and wildlife program is funded by power revenues. In 2012, funding amounted to US$248.9 million and supported a range of actions including habitat improvements and riparian restoration to improve water quality. The intended result is "a basin-wide vision for fish and wildlife with a comprehensive, underlying framework of general scientific and policy principles that apply to the entire Basin, including its vision, biological objectives, strategies, procedures and guidelines" (Leonard et al. 2015, p. 91).

The Council's approach incorporates many characteristics IISD has found to be indicative of adaptive policies—policies that are adaptable in the face of stressors such as climate change (Swanson & Bhadwal, 2009). In fact, the Council's plans in recent years have increasingly stressed the need for "adaptive management approaches to address uncertainties" (Leonard et al., 2015, p. 93). Key features of adaptive policies include regular policy review, the inclusion of forward-looking thinking (foresight), multistakeholder deliberation, access to resources (money, expertise and information) and the use of appropriate policy instruments. Relevant features of the Council's approach include the following:

- Updates of the Power Plan and Program every five years
- Regular and publicly available reporting
- Collaborative development, especially of sub-basin plans, with federal, tribal, state, county, non-governmental and other interested individuals, and incorporation of inputs into Program planning (Leonard et al., 2015)[4]
- Increased consideration by the Council of the effects climate change might have on ecosystems and power generation, including increased summer demand for energy (e.g. for air conditioning) competing with ecosystem service needs (e.g. water release to aid fish passage) – all when total water availability may decrease.
- Development of indicators, monitoring and evaluation, as well as quantitative goals and objectives

The Council is recognized as a leader in large-basin planning and the use of water management tools such as water banking, a market-based approach that helps "make water available for new uses, such as increasing stream flows and providing water for development" (Washington State Department of Ecology, 2015). Leonard et al. (2015) write, "Blending these water management tools with ecosystem preservation and restoration activity is a scientific art that is in its infancy. It seems likely that strategies and techniques for using these water management tools for hybrid human/ecosystem purposes may increasingly be the future focus of integrated fish/power and societal problem-solving across the many jurisdictions and ecosystems of the Basin" (p. 96).

The Canadian portion of the basin, which makes up 15 per cent of the area, is also seen as an innovator and leader in basin management. Here, the Columbia Basin Trust (CBT) was created "to support efforts by the people of the Basin to create social, economic and environmental well-being in the Canadian portion of the Columbia River Basin—the region most affected by the Columbia River Treaty" (CBT, 2015). This 1964 agreement between the United States and Canada sought power generation and flood control benefits for both countries but lacked other considerations, such as effects on habitat. In 1995, these interests became more interconnected when the Columbia Power Company (CPC), a crown corporation, was created by the Columbia Basin Accord and given the primary mandate "to undertake power project investments as the agent of the Province in partnership with Columbia Basin Trust" (CPC, 2015). Through the Accord, the CBT and CPC were given US$500 million to develop joint venture projects, with income shared equally between the two entities.

Just as with its American counterpart, the CBT is striving to increase adaptive capacity in light of climate change. Anticipated risks associated with climate change include changes in "glacial runoff, water temperature, freeze/thaw cycles, diseases and pathogens, flooding, frequency of droughts, severity of wildfires, landslides, avalanche risk and biodiversity" (Warren & Lemmen, 2014, p. 275). Efforts to increase the use of adaptive management have included the establishment of workshops involving multiple stakeholders to help "mainstream adaptation efforts throughout the basin" (p. 275).

[4] For example, stakeholder concerns about toxins and invasive species are reflected in the 2014 plan (Leonard et al., 2015).

5.2 Murray-Darling Basin

A drought in Australia in the 2000s that only officially ended in 2012 underscored the need for watershed management in one of the largest and driest river basins in the world: the Murray-Darling Basin in the interior of southeastern Australia (see Figure 7) (Murray-Darling Basin Authority [MDBA], 2014).

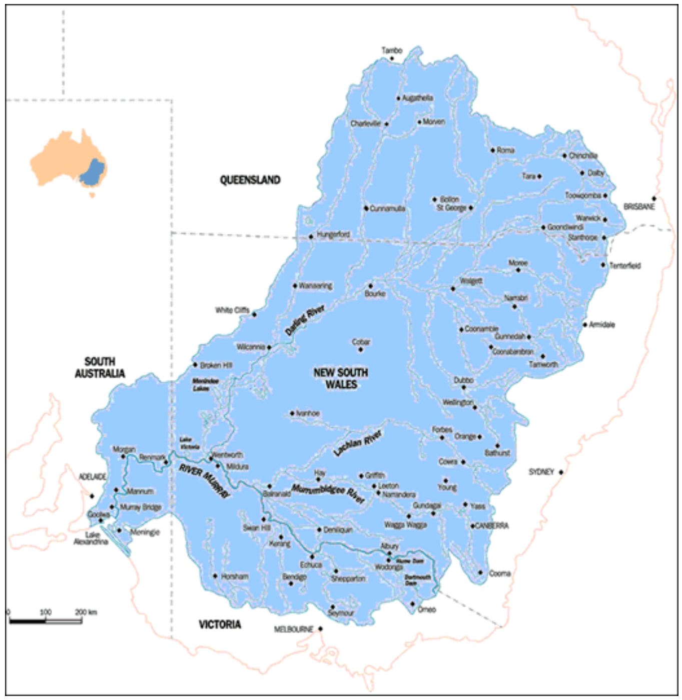

FIGURE 7. MURRAY-DARLING BASIN

Source: Commonwealth of Australia (2013)

The Murray-Darling Basin Authority (MDBA) was created through the federal Water Act 2007, with the purpose of undertaking "activities that support the sustainable and integrated management of the water resources of the Murray-Darling Basin in a way that best meets the social, economic and environmental needs of the Basin and its communities" (MDBA, 2014).

The functions of the MDBA include managing water sharing between states, monitoring water resources, managing water resources for environmental values, and constructing and operating dams and weirs on the River Murray (2014).

From 2007 through 2012, the MDBA undertook a process to develop a management plan over the more than 1-million-square-kilometre basin, an area that includes five Australian states and territories. This consultation engaged stakeholders on a broad scale, involving 175 meetings, consultations with "environmental groups, local government, State Governments, irrigators and technical specialists," and the receipt by the MDBA of "nearly twelve thousand submissions," resulting in "300 changes to the draft Basin Plan" (Horne et al., 2014).

The resulting Basin Plan became law in 2012. Designed as an adaptive framework, it will not be fully implemented until 2019 and is open to periodic review beyond then (MDBA, 2015a).

Key elements of the Basin Plan include the following:

- An "environmental watering plan" meant to ensure "that the size, timing and nature of river flows will maximise benefits to the environment to optimise environmental outcomes for the Basin" (MDBA, 2015a).
- A water quality and salinity management plan, which includes "objectives and targets for the Basin's water resources" (MDBA, 2015c).
- Requirements that the four state water resource plans will need to comply with, including incorporation of the environmental watering, water quality and salinity plans, "some aspects of water quality trading," inclusion of indigenous values, and monitoring (MDBA, 2015d).

- The creation of a mechanism to manage water in times of drought, creating tiers of "critical human needs" based on drought severity (MDBA, 2015b).
- Requirements for monitoring and evaluation of the basin plan.

A centrepiece of the plan includes decreases in surface water entitlements by 2,750 gigalitres (2.75 cubic kilometres) per year, to be achieved in part by economic mechanisms such as water quantity trading. In this system, water entitlements are redistributed through trading, with irrigators who require more water able to buy from others in the basin who have more than they need, including in other states. The AU$10 billion promised spending by government also includes "water buybacks" by government to help ensure environmental flows (Commonwealth of Australia, n.d.).

5.3 Transboundary River Basins on Six Continents (an IISD Analysis)

The organizations implementing large-basin management in the Columbia River Basin and Murray-Darling Basin have encountered a range of challenges including difficulties identifying and measuring basin-wide indicators, disagreements during collaborative processes and struggles integrating anticipated challenges of climate change and other stressors, such as human population growth, into planning. Based on IISD's experience analyzing basin management, such struggles come as no surprise. In a 2011 analysis of basin management in seven different transboundary river basins on six continents, IISD observed that developing management plans in large, multi-jurisdictional basins is, perhaps by definition, highly challenging (Roy, Barr, & Venema, 2011). Fortunately, many of the case studies also showed promise and progress.

The report considered the Danube, La Plata, Congo, Okavango, Red River, Mekong and Jordan River basins, evaluating the degree to which each had incorporated ecosystem services into their integrated water resources management (IWRM)[5] approaches. The authors' position was that robust integration of ecosystem service considerations into IWRM would lead to multiple benefits throughout the watershed, including "climate regulation, water regulation, natural hazard regulation, energy, freshwater nutrient cycling, water purification and waste treatment, disease regulation, primary production, fisheries and recreation, and ecotourism." This perspective was founded in part on statements by renowned global studies and institutions such as the Intergovernmental Panel on Climate Change, the Millennium Ecosystem Assessment and the International Water Management Institute indicating it would be prudent to manage watersheds for such multiple benefits, particularly in order to reduce vulnerability to climate change (Kundzewicz et al., 2007; Millennium Ecosystem Assessment, 2005; Molden, 2007).

However, IISD's 2011 analysis found that while all basins had IWRM frameworks, most focused on traditional considerations such as water quantity, navigation and hydropower—considerations that have long been the basis for transboundary agreements (e.g., the 1969 La Plata Treaty, which emphasized hydroelectric and navigation)—not the less conventional ecosystem services such as water purification and natural hazard buffering that have increasingly entered water management conversations in the 21st century. While hydropower generation is also a valuable and necessary ecosystem service, the analysis suggests that focusing only on these traditional considerations does not manage the basins to produce their full benefits and can cause unanticipated damages and losses in areas that are not explicitly considered.

[5] IWRM is "a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Global Water Partnership, n.d.).

Identified hurdles to greater integration of ecosystem services included political challenges (e.g., lack of buy-in from all basin countries), institutional challenges (e.g., decision making entrenched in silos and sectors, such as agriculture and energy), financial challenges (i.e., inadequate funding for effective IWRM) and technical challenges (e.g., the need to develop and use tools for data collection, financial mechanisms).

Nonetheless, evidence was found in many of the basins of growing integration of non-conventional ecosystem services. Highlights included the following:

- Development of financial mechanisms that encourage ecosystem service provision, such as payment for ecosystem services[6] in the Okavango and Danube Basins.
- Analysis of "ecological infrastructure" in the Red River Basin, such as wetlands for water purification (in complement to human-built water treatment plants) and consideration of how land management could restore or enhance this infrastructure.
- Ecosystem-based economic valuation of wetlands in the Mekong River Basin for such benefits as agricultural production, fisheries, flood mitigation, climate regulation, recreation, cultural significance and biodiversity.
- Opportunities to partially finance IWRM through carbon markets, particularly in the Congo River Basin.

[6] Payments for ecosystem services are "payments to farmers or landowners who have agreed to take certain actions to manage their land or watersheds to provide an ecological service" (International Institute for Environment and Development, n.d.).

6.0 Discussion

Topics raised repeatedly during the Lake Winnipeg regulation scoping session included climate change and eutrophication (CEC, 2014). The subsequent process has seen these concerns mentioned repeatedly during consultations. In addition, the topics of floods and droughts have been raised during various sessions and submissions (e.g., CEC, 2014, "Selkirk"; McCorrister, 2014).

Through this submission, IISD wishes to emphasize the relevance of climate change, nutrient loading, floods and droughts to decision making around Lake Winnipeg management. While we recognize that the focus of the hearing is Lake Winnipeg regulation, we urge consideration of this issue within the larger context of upstream factors, considering the whole drainage basin, where applicable. Focusing management for these concerns on just Lake Winnipeg itself is, in some respects, treating the symptoms (algal blooms and highly changeable lake levels[7]) rather than the disease, an altered watershed that has lost many of the ecosystem services that would naturally help control for nutrient loading, floods and drought. Of all the large lakes in the world, Lake Winnipeg has the smallest storage capacity relative to its basin size, with a volume:basin index of 0.000288. The index for Lake Superior is 329 times greater, suggesting that the case of Lake Winnipeg is unusual.

By considering the entire basin, rather than only the lake, innovative and cost-effective options to address challenges arise. For instance, Manitoba Hydro (2014) states, "The degree to which the [lake] level is affected depends on *inflow*, precipitation, evaporation, and outflow. Of these, Manitoba Hydro activities only affect outflow from Lake Winnipeg" (p. 65). We suggest that Manitoba Hydro has the opportunity to influence a second of these factors: inflow. Through the use of landscape management techniques discussed in this paper, such as distributed storage approaches (e.g., the North Ottawa project, South Tobacco Creek) and wetland restoration, a distributed reservoir could be created upstream. In addition to storing water, these areas would capture nutrients, provide water in times of drought and buffer against climate change. In addition, new economic opportunities would arise through potential to develop biomass resources (see, for instance, Grosshans et al., 2013) and new habitat would be created. Baker, Griffis and Ochsner (2012) even see opportunity in the U.S. Midwest for supplemental agricultural irrigation (in addition to nutrient and flood control) through innovative water management techniques.

Worldwide, basins are increasingly using large-basin management approaches to address complex challenges. As the case studies on the Columbia River and Murray-Darling basins illustrate, such comprehensive approaches are challenging. However, they are increasingly seen as the future of watershed management, grown out of the related concepts of IWRM and ecosystem services thinking. Both of these approaches optimize multiple benefits and, with many watersheds facing multiple problems and limited resources, solutions that address multiple challenges are appealing. In addition, the market value of actions such as hydropower generation is balanced with non-market, yet valuable, benefits such as flood protection and nutrient management. This is particularly relevant in a time of increasing climate impacts and decreasing resources to deal with these complex problems. Kundzewicz et al. (2007) write of the capacity of IWRM planning:

[7] We recognize that because it is a shallow lake, Lake Winnipeg's levels will respond quickly to water inputs no matter what management is done upstream. What we suggest are some actions to buffer these effects.

> It can be expected that the paradigm of Integrated Water Resources Management will be increasingly followed around the world, which will move, as a resource and a habitat, into the centre of policy-making. This is likely to decrease the vulnerability of freshwater systems to climate change. (p. 181)

Therefore, this paper presents the case that the CEC should recommend the integration of large-basin management thinking into lake regulation and related power licence processes and decisions. From a governance perspective, the responsibility for large-basin management to produce these benefits should be shared. Manitoba Hydro, as a steward and beneficiary of the lake, has a role to play in supporting upstream management to ensure lake health, and it should be viewed as a collaborator in such an endeavour along with relevant government agencies, non-governmental organizations and civil society. As with the case studies outlined in this document, a wide range of stakeholders from various levels of government, businesses, industry, agriculture, First Nations communities and civil society organizations should be engaged. A collaborative, basin-wide process is important to ensure buy-in from basin stakeholders. In some regions where large-basin management is occurring, federal or provincial/state governments are the leaders. In others, new entities are created, sometimes by legislation, and given mandates to manage basins for both ecosystem and human benefits.

Hydroelectric power is an ecosystem service that benefits Manitoba through clean energy production, economic returns and a large range of affiliated benefits and, as has been the case in other watersheds around the world, was one of the initial drivers for large-scale watershed management. With increased understanding in recent decades of other services provided by watersheds, management can now broaden to include a new array of benefits, including nutrient and carbon sequestration, water storage, and climate change buffering.

7.0 Summary and Recommendations

In this submission, we discuss how the size of the Lake Winnipeg watershed—nearly 1 million square kilometres—compared to its relatively small lake surface area and volume presents challenges (e.g., in terms of low water storage capacity) but also opportunities. By having such a large area upstream, we can strategically manage the landscape to partially address many concerns regarding the lake, especially nutrient loading and climate change risks, before waters even reach the lake itself. Management can be designed to produce multiple benefits throughout the basin, such as flood and drought mitigation, nutrient capture, carbon sequestration, improved water quality, and economic opportunities including protecting reliable hydropower generation by Manitoba Hydro.

TABLE 4. KEY RECOMMENDATIONS

- Enhance basin-wide management and governance.
- Consider the land as infrastructure.
- Invest in upstream management, including storage to influence Lake Winnipeg levels and power generation.
- Use financial mechanisms to generate ecosystem services.
- Manage upstream for nutrient capture.
- Manage upstream for climate change adaptation and natural hazard buffering.

Below we detail recommendations, summarized in Table 4, that would enhance ecosystem services in the watershed, help address several of the concerns being considered by the CEC and support sustainable development principles. These recommendations could be implemented in a variety of ways, and by a variety of institutions, including but not limited to Manitoba Hydro, the Province of Manitoba, and other organizations working on Lake Winnipeg management and related issues. Some actions require buy-in from a broad range of stakeholders from all or most provinces and states in the basin. This includes not just provincial and state governments, but also industry, businesses, the agricultural sector, non-governmental organizations, municipalities and federal governments. Achieving basin-wide support for some of the actions below would require leadership from the province of Manitoba and would benefit from Manitoba Hydro's support, as well as its scientific, technical and hydrologic knowledge.

Enhance basin-wide management and governance

In lakes and rivers throughout the world, we're seeing issues pertaining to water quality, quantity and access for human and environmental needs. A desired way of managing these systems strategically is through comprehensive, whole-basin management, considering all the different benefits, or ecosystem services provided, and collectively prioritizing these as a watershed community.

Decisions pertaining to Lake Winnipeg regulation and related power licensing must be considered in the context of the entire basin. In order to understand all the benefits of the Lake Winnipeg and downstream regions where Manitoba Hydro operates, a basin-wide undertaking should include bringing together the different agencies working on social, environmental and economic issues to give a strong sustainable development perspective of the basin. A collaborative effort must then be used to determine priorities and investments in this basin, to ensure not only that we are collectively prioritizing certain benefits, but also that no one is harmed by these decision. A collaborative process provides strategic input into future licensing discussions and should lead to systematic reviews of energy needs and decisions in the basin.

In order to achieve large-basin management planning, we recommend the creation of a basin-wide, transboundary body with a mandate to consider multiple ecosystem benefits in the basin (e.g., nutrient capture, climate regulation, water purification, water storage, energy, fisheries, tourism, recreation and hydroelectric power generation) or the use of an existing entity to perform this function. We emphasize that Manitoba Hydro can be only one part of this solution, and that involvement from provincial governments (with Manitoba as a leader), state, federal and municipal governments is essential, along with inclusion of other affected and interested stakeholders (agriculture, other energy producers, industry, First Nations, non-governmental organizations, academics, etc.).

As an example to learn from, we point to the Columbia River Basin and the Murray-Darling Basin, though we also recognize that each basin is different and that Lake Winnipeg may require its own model. However, based on our research on large-basin management and IWRM, we are able to recommend that several key characteristics be included:

- The incorporation of management for a broad range of ecosystem services (e.g., nutrient capture, water storage, climate regulation and hydro production) in the mandate of any organization charged with directing basin management.
- Broad and meaningful collaboration and consultation with a range of stakeholders throughout the basin, and incorporation of inputs into decision-making on basin management.
- A sound basis in scientific evidence, possibly with independent scientific review of planning.
- The development of goals, objectives, timelines and targets (stakeholders should be engaged in shaping these goals).
- Monitoring of progress toward goals and adequate funding to conduct this monitoring.
- The incorporation of adaptive mechanisms into planning (i.e., ensuring there is flexibility to alter course if desired outcomes are not being met).

Another example is the International Joint Commission's facilitation of the creation of the international Rainy-Lake of the Woods Watershed Board in 2013 to "assist it with binational coordination of water quality efforts for the entire transboundary watershed and to coordinate the management of the water levels and flows" (International Joint Commission, 2013). We are encouraged by this development and hope it will provide inspiration for further transboundary watershed management and international collaboration between the United States and Canada.

While in our discussion of large-basin management planning we refer to the "Lake Winnipeg Basin," we also include the Nelson River Basin (which actually includes all of the Lake Winnipeg Basin). The Lake Winnipeg Basin is upstream of the Nelson River and, therefore, activities ultimately have effects on the Nelson itself. We believe that the most beneficial and balanced management would result from the entire area of the Lake Winnipeg and Nelson River basins being considered in an integrated manner. Sub-basin planning (for the Nelson River, Red River, etc.) is still necessary, but increased integration of connected basins is essential.

The Lake Winnipeg Basin may already have a foundation for basin-wide management through the province of Manitoba's Lake Friendly Accord and Lake Friendly Stewards Alliance, which could help build the network and will to manage the basin collaboratively. The Accord was created "as a way of coordinating action toward a common goal of improving water quality by reducing nutrients through the engagement of all," and to-date has been signed by the Government of Manitoba, the Government of Canada, the state of Minnesota, the South Basin Mayors and Reeves and the Red River Basin Commission (Government of Manitoba, n.d.).

Consider the land as "infrastructure" and the whole basin as an asset

We suggest that by focusing on affecting water quality and quantity in Lake Winnipeg by only considering the lake itself, we consider only part of an interlinked system. Lake Winnipeg itself offers only 284 cubic kilometres of volume and 23,553 square kilometres of surface area for management. However, its drainage basin presents nearly 1 million square kilometres of land to manage. We recommend that Manitoba Hydro and other decision-makers view the land and ecosystems upstream as potential "ecological infrastructure" that can be managed for such benefits as improved water quality (complementing human-built treatment plants) and water storage (complementing concrete storage structures).

In fact, we suggest that upstream storage could be seen as a way to influence Lake Winnipeg water levels, though modelling is needed to explore further the feasibility of this approach. This idea is discussed more in the next recommendation.

Prioritize upstream storage in management decisions to influence Lake Winnipeg levels and power generation

As noted previously in this report, Manitoba Hydro (2014) states, "The degree to which the [lake] level is affected depends on inflow, precipitation, evaporation, and outflow. Of these, Manitoba Hydro activities only affect outflow from Lake Winnipeg" (p. 65). We suggestion that Manitoba Hydro has the opportunity to influence a second of these factors: *inflow*.

We encourage Manitoba Hydro and other stakeholders to view upstream storage in wetlands and distributed storage systems (e.g., similar to the North Ottawa project) as reservoirs tied into hydro. The volume of Lake Winnipeg as a reservoir is small, but water could also be stored upstream rather than in the lake itself, resulting in additional benefits such as reduced overland flooding, increased nutrient capture and new economic opportunities. Such investments would also align well with the provincial Surface Water Management Strategy.

We suggest that the first steps for investigating upstream storage would be to model the amount of water that could be stored in the basin and to conduct benefit-cost calculations that factor in ecosystem services such as the value of carbon storage, reduced flooding, drought-proofing, economic opportunities and nutrient capture (see Dion & McCandless, 2014).

Use financial tools and instruments to generate ecosystem services

We recommend that financial tools and instruments be used to increase water management for ecosystem service provision. Hydro is an important service we should continue to produce, but we suggest that increased watershed management for other ecosystem services would not only help address concerns raised in the CEC review process (e.g., nutrient levels, water flows and climate change concerns), but would also produce additional ecosystem service benefits such as carbon sequestration, new economic opportunities and social benefits. Various financial approaches could encourage ecosystem service provision. Basins profiled in section 5 of this paper illustrate how these approaches are being used in other jurisdictions. We propose the following as possibilities to consider:

- Water quality trading.
- Payment for ecosystem services.

- Ecosystem service valuation (to provide the rationale for investment).
- Funding ecosystem service–focused management through approaches such as that used by the Columbia River Basin, where some share of hydro revenues goes to support management and where joint venture projects with watershed management organizations produce revenues that are used in part to protect and enhance ecosystem services.

Manage upstream for nutrient capture

Scientific evidence to date does not support the concept of Lake Winnipeg regulation being a major cause of eutrophication. We do not believe Lake Winnipeg regulation is contributing in a significant way to nutrient loading. However, without evidence that regulation makes no contribution at all, we suggest it is appropriate that Manitoba Hydro support nutrient management upstream, rather than in the lake itself. IISD has found that upstream interventions to control non-point nutrients can capture large amounts of phosphorus and nitrogen.

Manitoba Hydro is one of the main stewards of Lake Winnipeg. As one of the lake's stewards and beneficiaries, it is part of Hydro's responsibility to take an interest in lake health and well-being. Notably, it already provides some support for nutrient management and nutrient-related research.

There are many ways in which Manitoba Hydro can help address nutrient loading. We suggest that actions related to *water flows* are highly appropriate, given that controlling inflows in high-flow years will have benefits not only in terms of nutrient loading, but also for hydro itself by storing water upstream (i.e., water storage is necessary for power generation). These actions could include conducting, funding or otherwise supporting wetland protection, wetland restoration, distributed storage, public education on "keeping water on the land" and research on best methods for upstream storage.

We also encourage Manitoba Hydro to be a leader by setting targets for itself on the amount of nutrients it will help prevent from entering the watershed (and challenge other lake and basin stewards and beneficiaries to do likewise). As mentioned in section 5, targets and goals can help motivate positive watershed management. We encourage Manitoba Hydro to consider multiple ecosystem benefits when selecting nutrient reduction mechanisms.

Manage upstream for climate change adaptation and natural hazard buffering

As with nutrient capture, some of the anticipated risks of climate change to Lake Winnipeg can be partially addressed via upstream management. The Lake Winnipeg Basin is naturally vulnerable to floods and droughts, and climate change is expected to exacerbate these risks with more frequent and intense events. Worldwide, watershed managers are increasingly considering climate change predictions in planning; according to the most recent Natural Resources Canada report on climate change (Warren & Lemmen, 2014), hydroelectric companies are highly aware of the potential effects of climate change due to possible effects on water availability for power generation.

Several of the recommendations above would also provide adaptive capacity against climate change. For instance, using the land for water storage could help reduce peak flows during floods and store water for use during droughts.

It is increasingly important to mainstream climate change considerations into watershed planning, with governments and institutions, such as the CBT, attempting to do so. We recommend that Lake Winnipeg Basin decision-makers, including Manitoba Hydro, do likewise.

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