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Out of control: How we failed to adapt and suffered the consequences

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ABSTRACT

International events, economic changes, and the impacts of climate change will test the Great Lakes–St. Lawrence River basin over the next five decades. The region's ability to effectively meet these challenges will require foresight, investment, and cooperation. As a contribution to this special issue, this paper presents one plausible 50-year scenario of the emergence of these challenges and the region's response to them. In it, early signs of economic, environmental, and governmental vulnerability are not adequately addressed. Investments aren't made to provide needed funding for monitoring and evaluation. The region's intellectual and environmental capital isn't leveraged, limiting the region's ability to address its economic and environmental challenges and compete with the rest of the world. The pursuit of local self-interest and short-term survival outweighs cooperation across jurisdictions and long-term planning. The vision of the future presented here is one in which the region's economy is dependent on stagnant extractive industries, its ecosystems are compromised, and its global standing is greatly reduced. In response to all of these developments, by 2063 hopelessness and violent tension is spreading throughout the region's population.

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Introduction

In order to avoid danger, one must first anticipate it. “Out of Control” describes five decades of challenges facing the Great Lakes–St. Lawrence River basin from 2013 to 2063. The scenario presented in this paper draws upon the insights of research in this special issue on the following major drivers of future change in the basin and surrounding Great Lakes region: invasive species (Pagnucco et al., in this issue), biological and chemical contaminants (Cornwell et al., in this issue), climate change (Bartolai et al., in this issue), demographics and societal values (Méthot et al., in this issue), the economy (Campbell et al., in this issue), energy (Kelly et al., in this issue), governance and geopolitics (Jetoo et al., in this issue), and water quantity (Maghrebi et al., in this issue), as well as technology (See Appendix A). This future history represents one of the four plausible narratives laid out in Laurent et al. (in this issue) based upon the intersection of two highly uncertain and highly influential forces present in the region: the human capacity for

change and an environmental and economic balance. As the most negative scenario explored in this issue, it describes the possible consequences of both a fragile environment and economy and a society incapable of changing to meet these challenges. The rest of the first section provides a short overview of the fifty-year period. In section 2, we provide a scenario narrative based on five decade-long descriptions before concluding in section 3.

Drifting towards the cliff

In 2012, the Great Lakes–St. Lawrence River region celebrated a high point in its global profile as a regional economic, environmental, and political leader as Canada and the US successfully amended their Great Lakes Water Quality Agreement (GLWQA; IJC, 2012). In 2063, this peak is viewed as a period of missed opportunity. Narratives of international comity and returning prosperity obscured concerns over shortfalls of moral commitment, specific objectives, science-driven monitoring, economic-savvy assessment, and considerations about impending climate change. For several decades, more and more alarming conditions were met only with apathy or mismanagement. As the magnitude of global climate change impacts emerged in earnest

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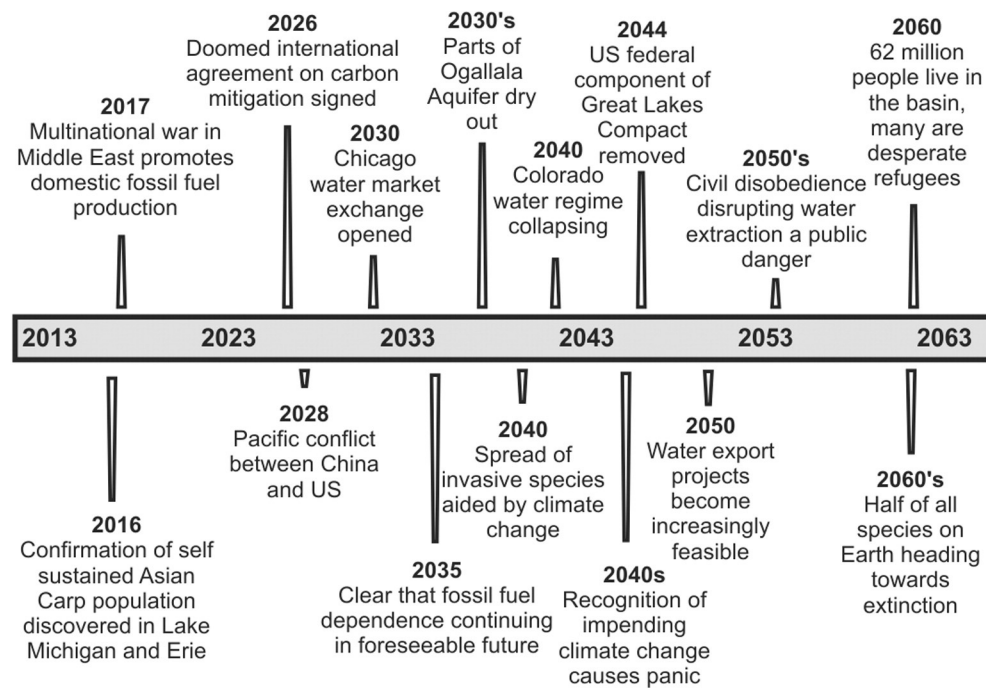


Fig. 2. Original artwork illustrating the outcomes of an “out of control” scenario for the Great Lakes–St. Lawrence River basin.

Leading into the decade of 2013–2023, this widespread sentiment was translating into tangible policies in the US. In 2007, the US Congress passed the Energy Independence and Security Act (EISA), setting targets for the production of transportation fuels from renewable energy sources, including conventional biofuels such as corn-based ethanol (Hehaffey et al., 2012). In 2010, the US Environmental Protection Agency (EPA) predicted that 15 billion gallons of conventional biofuel would be produced by 2022 (Hehaffey et al., 2012). That same year, 25% of the total US corn-growing acres that could be used for ethanol production were in the Great Lakes states (MSUPC, 2010). In 2013, the Great Lakes states pushed for the adoption of renewable energy through Renewable Portfolio Standards that required local utilities to generate a minimum percentage of electricity from renewable sources. In 2009, Ontario passed the Green Energy Act which offered benefits such as Feed-in-Tariffs to support generators of energy from renewable sources. The federal government released a Renewable Fuels Strategy and offered incentive programs such as the Biofuels Opportunities for Producers Initiative, the ecoAgriculture Biofuels Capital Initiative, and ecoEnergy for Biofuels. The first two were canceled in 2008 and 2012, respectively (CRFA, 2013), and the last was canceled in 2017.

For obvious reasons, the Great Lakes region at that time also enjoyed opportunities to promote economic development efforts centered on products and services related to water. Unfortunately, the vision, leadership and initiative that could have coordinated and leveraged such localized development opportunities across the Great Lakes region never materialized. Meanwhile, global events were about to start putting the region's capacity to govern itself to the test.

During the 2013–2023 decade, climate change transitioned from projected to real-world consequences. As the oceans absorbed excess heat, global air temperatures rose slightly less than expected (Meehl et al., 2013), fueling continued skepticism and inaction on climate change. However, large El Niño events coinciding with the shift from recent global warming of the oceans back to the atmosphere resulted in particularly destructive years of weather conditions. World food production was significantly undermined, further destabilizing food markets (Subbaraman et al., 2010) and placing additional pressure on an already fragile Middle Eastern region (Johnstone and Mazo, 2011). As an ominous portent for the coming decades, the prevailing instability

provided an opportunity for extreme nationalist and fundamentalist elements to emerge.

As conflicts throughout the Middle East metastasized, the global economy, which had been slowly improving following the Great Recession, began to drag again and the US's debt began to re-inflate as defense spending rose. With tensions only tentatively contained and energy markets still volatile, the commitment to North American resource exploration and extraction became a truly unstoppable political force across the continent. Hydraulic fracturing (also referred to as fracking) became a pillar of energy policy. Development of the Alberta oil sands accelerated, supported by extensive pipeline networks on both sides of the border.

The region was also negotiating its own environmental issues. The first ominous event signaling that this period of relative calm was coming to an end was the confirmation of a self-sustaining Asian Carp population in the Lake Erie Basin and then in Lake Michigan (Fig. 1). Calls for additional funding, surveillance, and regulation had failed despite the discovery of minor invasions into the lake system (Jerde et al., 2013) and successful spawning within the basin (Chapman et al., 2013). In a political climate already increasingly characterized by laissez-faire government retrenchment, scrambling politicians and angered residents came to interpret this failure as evidence of scientific and regulatory futility rather than evidence of its necessity. This skepticism also led to inaction in enhancing invasive species regulations such as tightening existing ballast water rules, banning within-basin transfers and reining in live-bait, food, and aquatic trade across the region. There was also a failure to follow through on ensuring that proper research, funding, implementation, and enforcement of water quality regulations occurred. Most prominently, if the region could have adjusted to manage the environmental impacts of conventional biofuel production or developed innovations in more efficient biofuel sources such as switchgrass, the boon to farmers and added stability of energy prices could have been beneficial. Unfortunately, this was not the case. Rising corn production driven in part by biofuel demand would come to have long term impacts on the basin. Larger and larger algal blooms in Lake Erie resulting from agricultural runoff expanded the annual ecological “dead zones” in the lake, spread harmful toxins along the coastline, negatively affected related tourism and property values, and resulted

in millions of additional dollars spent on water treatment annually (IJC, 2014; Michalak et al., 2013).

As the decade came to an end, the foundation for a dark future was laid. Government at all levels on both sides of the border had become so focused on dealing with their debts that other important aspects of governance began to fall away. Reductions in oversight led to poor decisions, and their negative effects rippled through the region. These seeds sown between 2013 and 2023 would be cultivated over the next few decades and reach full bloom mid-century.

2023–2033: doubling down

“Yeah, I’d complain about missing wildlife or the fact that I haven’t had a chance to ice fish in a couple years, but frankly, I’m far too busy trying to make ends meet what with food costs and this messed-up economy. Guess that’s how we got in this mess in the first place though, huh?”—Paul Williams, unemployed in Northern Michigan, 2032

From 2023 to 2033, the clouds that had formed in the previous decade thickened and became more ominous. Global developments and poor policy responses continued to sap the Great Lakes region’s economic vitality. The ramifications of climate change became more tangible. As an example, during the 2020s, many ski seasons in Ontario were already almost half a month shorter than they had been between 1961 and 1990 (Scott et al., 2003). With enhanced attention and urgency aimed towards addressing climate change, much of the international community began to incriminate the Great Lakes region, focusing on the extraordinary resource extraction occurring in and around the region. The Great Lakes region was painted with a wide brush that lumped together the “dirty oil” from Alberta and the sparsely regulated natural gas industry. As the national environmental profiles of both Canada and the US declined, the region’s global standing diminished.

Despite concerns about climate change impacts, support services for oil sands and natural gas development continued to be major economic drivers in the region. Oil sands development in Alberta continued unabated, assisted by pipelines, transportation and refinery developments in the Great Lakes region (Hansen, 2013). Natural gas expanded as a profitable and politically viable alternative due to its reputation as a cleaner form of energy production. The banner of energy independence obscured research that raised red flags about the environmental quality impacts of the oil sands (Kelly et al., 2009; Kurek et al., 2013) and hydraulic fracturing (Warner et al., 2012) as well as their contributions to climate change (Karion et al., 2013; Swart and Weaver, 2012; Tollefson, 2013).

Citizen watch groups, NGOs and even state-level governments became organized against the environmental consequence of hydraulic fracturing on water quantity and quality. During the hydraulic fracturing process, large quantities of water are mixed with sand and chemicals in order to adequately free the supply of natural gas or oil from the rock (Andrews et al., 2009). Staggering amounts of water were contaminated by tens of thousands of gallons of chemical additives such as lead, benzene and methanol, leaving the water untreatable and consequently unusable. The further development went, the more water and chemicals were needed, accelerating the contamination and draining of the region’s groundwater resources over time. The proliferation of local sites of contamination eventually had regional impacts, undermining binational water quality cooperation.

The increasing focus on fossil fuel development also undermined the desire of those in the region to invest in other forms of economic development. At the same time, drastic federal spending cuts were leaving states, municipalities, NGOs and potentially innovative private industries without a competent partner and funding source. As a result, crumbling infrastructure was allowed to decay further, programs not deemed vital faced budget cuts, and monitoring work to assess compliance and effectiveness were ill equipped. When funding was available, it was often assigned on an ad hoc basis depending on the clout of the local

representative as a means to appease constituents in a given jurisdiction rather than as a part of a larger initiative or plan that would have had broader-reaching effects. This lack of foresight and initiative squandered the opportunity presented by the Great Lakes region’s substantial non-fossil fuel energy resources. Research on positive feedbacks between environmental protection and the manufacturing sector (Bezdek et al., 2008) was ignored. The remarkable offshore wind energy potential (Adelaja et al., 2012), considerable solar energy potential (Wiginton et al., 2010) and cellulosic biofuel capacity (Hacatoglu et al., 2011) could have found a fertile testing ground and innovative industrial foundation based on the region’s universities and historical manufacturing prowess, but the opportunity was missed.

At the global level, the record-breaking extreme weather conditions in the previous decade gave new life to international efforts to reduce greenhouse gas emissions. The resulting 2025 Agreement Remediating Climate Change (ARCC) was hailed as a major accomplishment that would halt and eventually reverse damage. For the first time, all of the worlds’ industrial powers locked themselves into an enforceable agreement to curb and cut their emission outputs. Unfortunately, the impracticality of enforcing such an agreement, especially in the face of continued international tensions, effectively incapacitated the agreement before it would have a substantial impact.

Tensions between North America and China had been slowly growing for several decades, especially following the aforementioned conflicts in the Middle East where China and the US diplomatically sided with regional allies that were opposed to one another. In response to growing mutual domestic unease, an unrelenting desire to retain control over fossil-fuel resources, and conflicting long-standing alliances, the two countries found themselves increasingly close to conflict in the Pacific. The conflict that eventually broke out was limited to scattered naval skirmishes, with both countries pulling back from a war that neither of them would actually undertake (Fig. 1). Though no clear victor could emerge, the consequences to the global economy were substantial, with the world’s largest trading relationship severely damaged. In the aftermath of the conflict, disruptions to supply chains and the nationalistic furor that followed resulted in investment between the US and China drying up. The corresponding stress on low wage labor markets meant higher prices on everyday items, adding another burden to a beleaguered North American economy. Without the cooperation of the world’s two largest carbon emitting countries, the enforcement of ARCC became impossible. As a result, international climate mitigation and adaptation strategies depended on international comity that became less influential as the world fragmented into divided camps. Though the impacts of climate change would become more and more palpable, large-scale reductions in emissions sputtered. Without dependable worldwide coordination, it proved impossible to significantly limit greenhouse gas production.

As the US prepared to celebrate its 250th birthday, the national mood was hardly one of celebration in the Great Lakes region. By the mid-2020s, the state of Illinois’ pension requirements placed it on the brink of catastrophe (Ingram and Dabrowski, 2013). Despite a last minute deal to save the state’s solvency, it came at the price of dramatic spending cuts, pension restructurings and a limited default that forced a dramatic shift in policy priorities (Malanga, 2013). Other state and municipal governments had little time or money for broad commitments and formerly willing partners looked to other regions as the fiscal situation within the Great Lakes region became too risky. Even economic issues seemed to fall at the wayside as cooperative ventures such as 2011 US Beyond the Border Initiative found their opportunities constrained by state and regional isolationism.

With other regions of North America experiencing stronger economic growth, the migration trend away from the rustbelt continued into the late 2020s, with much of the out-migration being younger college and university graduates looking for employment. The region hadn’t invested in innovative sectors in the previous decade and now it lacked the resources and trained workforce to respond to changes

in the economy brought on by technology. The Chrysler Assembly Plant in Windsor, Ontario provides an excellent example of the kind of downsizing that was occurring. In 2013, this auto plant had approximately 4700 employees (4518 hourly; 180 salaried) (CGM, 2013). Through the 2010s and 2020s this number was reduced to some 1000 hourly employees, almost all of who had some form of graduate level education in engineering or an advanced trade's certification. The emergence of new technologies such as 3D printing, nanotechnology and cognitive computing only enhanced the need for skilled research, development and machine supervision over physical labor. While the turn from depending on cheap factory hands could have enhanced the viability of regional manufacturing, companies found that they could also find the needed expertise abroad and easily import it through foreign worker visa programs (Kirkegaard, 2005). Similarly, manufacturing on both sides of the border saw a labor contraction from 2023 to 2033. Many long-time employees found themselves on unemployment rolls as this technological revolution unfurled. The impact of these changes to manufacturing meant that many "blue collar" laborers were forced into lower paying service sector jobs as better opportunities were now out of reach. As a result of these tough economic times, the US Great Lakes states continued to see the gradual population contraction that had plagued the Rust Belt for decades.

In Canada, although the manufacturing sector faced many of the same challenges, the service industries of the emerging megacity in the Golden Horseshoe of Lake Ontario provided an economic baseline that limited out-migration away from the Great Lakes region. Instead, this area became a center of immigration both from abroad and from drought-stricken areas in the United States. Some of these incoming residents could potentially be classified as environmental refugees moving from increasingly environmentally challenging locations to an area that at least had relatively stable weather conditions and enough freshwater to survive.

Those forced to move into the region would not be the only ones to notice these freshwater resources. In late 2030, the Chicago Mercantile exchange announced that it would open a water exchange, joining the cities of Frankfurt, London and Shanghai as centers of trade for this increasingly valuable commodity (Fig. 1). Though agreements covering the Great Lakes region restricted drawing water from the lakes themselves, residents took notice as the long-awaited challenge to these restrictions began to materialize in the 2030s.

2033–2043: the wolves at your door

"To tell a family living in the Great Plains that they can't buy water from those in the Great Lakes who wish to sell it is profoundly un-American!" – US Senator Austin Baker of Oklahoma (R) October 18, 2035

In the years 2033 to 2043, the Great Lakes region's economy became increasingly obsolete. While global momentum towards addressing climate change picked up, the Great Lakes region became lumped in with the massive fossil fuel extraction efforts surrounding the region, lowering the basin's reputation as an international example of environmental governance and economic innovation. In this decade, individual governments and citizens faced the choice of whether to individually profit from their shared cross-border resource, the lakes.

With a languishing regional economy and the spirit for political cooperation between governments throughout the region at an impasse, the necessary resources to expand and properly monitor environmental regulations continued to prove elusive. Industries threatened to leave the region or go bankrupt if they couldn't retain unnecessarily-polluting infrastructure or were relieved of unwanted regulation.

The degradation of the region's ecosystems and economy became self-reinforcing. As environmental conditions worsened, reversing the damage grew more costly, making the realization of economic benefits

from doing so less discernable. Commitment to protecting the Great Lakes from contamination evaporated and money needed to address the dangers challenging them didn't materialize. The failure of binational agreements to protect shared ecosystems undermined other initiatives. Protectionist policies became the first line of defense in an attempt to stave off the effects of the continued economic depression.

Biofuel production was eventually abandoned by 2035, as the global cost of corn and other agricultural goods rose in the face of continued climate-induced drought. Other opportunities for regional industries to adjust to changing global conditions were also missed. Steadily, the region's products became less globally competitive. Products produced in the region were still being designed for a fossil fuel-powered society that prevailed locally but many potential markets were trying to move away from.

However, the Great Lakes region was gaining attention for another potential export. The first real signs of trouble began in the late 2020s when the Ogallala Aquifer, which fed the freshwater needs of the agriculture-intensive Great Plains, began to show more and more signs of impending exhaustion. By the early 2030s, irrigation became no longer feasible for large portions of the southern High Plains running in between Texas, Oklahoma, New Mexico, Nebraska and Colorado. Southern portions of this "fossil water" source left over from the last ice age began running too low to support irrigation (Scanlon et al., 2012). The states in that region had suffered from climate change-influenced "dust-bowlification" (Romm, 2011) due to a sustained drought lasting over a decade, and sustaining the Great Plains' agricultural production became a national issue (Fig. 1). A lobbying effort across much of the United States attempting to divert water from the Great Lakes–St. Lawrence River basin to the Great Plains was initially countered with effective resistance from a broad coalition of political and social groups within the region. However, over time those arguing for transferring water were able to effectively make the case that with food security issues deepening worldwide, the US needed to be able to salvage its productive agricultural areas. Ambitious politicians across the country began supporting the removal of the federal component of the Great Lakes Compact.

The global market for water was also expanding, creating a greater incentive for export. Some companies took advantage of the Great Lakes Compact's non-bulk transfer loophole to turn the basin into a greater exporter of water in containers smaller than 5.7 gallons (See Dornbos (2010) for an overview of the argument both for and against this loophole's significance). Meanwhile, spurred by rising water prices and growing national support, other firms began developing plans for transport to the Great Plains via the Missouri River basin.

Even with many of these plans still only in development, the steady decline in Great Lakes' water levels was becoming clear. Between 2013 and 2023, real uncertainty remained about changes in future lake water levels based on projected climate change scenarios (Gronewald, 2013). Eventually, the passage of decades made it clear that climate change was going to be a driver that caused lake levels to go down. Greater lake evaporation due to warming temperatures eventually became a more important factor than increased rainfall for the lake system.

Though these declines were not yet dramatic, they exacerbated other problems that the basin was experiencing. For many decades, the establishment of invasive species in the region had been replacing native populations with fewer, more dominant, invasive ones (Ricciardi, 2001). As this feedback process picked up, the region's ecological systems were becoming less diverse (Mooney and Cleland, 2001), less productive, and less capable of adjusting to further environmental changes (Olden et al., 2004). In commercial terms, both the industrial and the sport fishery industry in the region had been in decline for several decades owing to the spread of invasive species along with market and other social changes (Rothlisberger et al., 2010). In the early parts of the century, regulation of ballast water and requirements for saline flushing for entering overseas ships appeared to have been successful in eliminating new transoceanic introductions into the system (Bailey

et al., 2011). However, with policymakers unwilling to promote regulation, evidence-based warnings had been ignored that concerned the limitations of the existing regulatory scheme such as existing non-compliance by transoceanic vessels (Bradie et al., 2010) the spreading of existing invasives through unregulated domestic ballast water (Niimi, 2004; Rup et al., 2010; Simkanin et al., 2009) and unregulated recreational boating (Murray et al., 2011). The consequences of that oversight were now starting to become apparent as high-impact species such as the “killer shrimp” (*Dikerogammarus villosus*) (Ricciardi and Rasmussen, 1998; Van Der Velde et al., 2000) and the amur sleeper (*Perccottus glenii*) (Copp et al., 2005; Reshetnikov, 2010) were able to survive their journey across the Atlantic in noncompliant vessels and establish dangerous viable populations in the lake system. Also overlooked at the time was the regulation of live trade, which provided the opportunity for invasives such as northern snakehead (*Channa argus*) (Chen et al., 2006) and certain Asian carp species such as bighead (*Hypophthalmichthys nobilis*), grass (*Ctenopharyngodon idella*) and silver (*Hypophthalmichthys molitrix*) to establish and spread rapidly (ACRCC, 2010).

Changing lake temperatures were also putting pressure on native species that were less tolerant of heat, creating new opportunities for invasive species whose success had previously been constrained by cold conditions. Warming lake temperatures alone could have generally enhanced the productivity of the region's fisheries (Lynch et al., 2010). However, without a coordinated, regional-scale adaptation strategy (Lynch et al., 2010), existing species were not provided with enough opportunities to adapt to their changing ecosystem. By 2040, average surface water temperatures across the Great Lakes had risen by about 1.5 °C (Erie) to 2.5 °C (Superior) (Trumpickas et al., 2009), making it possible for new species to establish themselves. These new species, such as the Asian clam (*Corbicula fluminea*), red swamp crayfish (*Procambarus clarkii*) and the bluespotted sunfish (*Enneacanthus gloriosus*) became established in Lakes Erie and Ontario, and the grass pickerel (*Esox americanus vermiculatus*), spotted gar (*Lepisosteus oculatus*) and river shiner (*Notropis blennioides*) spread up into Lake Superior (Mandrak, 1989). The warmer lake water temperatures and the reduced coastlines created the perfect environment for the spread of the invasive common reed *Phragmites* (Solomon et al., 2007). As the shoreline receded, former coastal wetlands dried out and *Phragmites* was able to outcompete native plants along the newly-formed shoreline (Tulbure et al., 2007; Tulbure and Johnston, 2010), permanently altering critical bird and fish habitats.

Climate change also intensified the stress that contaminants were having on the health of the Great Lakes ecosystem. The 1972 GLWQA, its updates, and related policies represented valiant efforts to restore and protect the water quality of the whole region, but ultimately proved insufficient. Policymakers in the early decades of the 20th century failed to address continued calls to redress the management regime's deficiencies in learning from experience and confronting the underlying sources of stress (Bails et al., 2005; McLaughlin and Krantzberg, 2011; McLaughlin and Krantzberg, 2012). So while some examples of progress could be noted, the last few decades still featured a steady accretion of contaminant issues similar to those at the beginning of the century that were now becoming more challenging due to climate change. Lower lake water levels and stronger storms also disturbed “legacy contaminants” that re-emerged due to either enhanced natural forces or costly dredging that temporarily preserved shipping lane capacity (Ng and Gray, 2011). Legacy contaminants are substances that have already been highly or completely restricted so their presence is inherited from a previous time (e.g. DDT and PCBs in North America). Legacy contaminants are sometimes considered contained when they are trapped in the environment and not influencing the larger ecosystem. One concern with climate change is that unprecedented extreme events, low lake levels, or adaptive activities (e.g. dredging) will expose the lake system to such contaminants previously locked-away in sediment (see Rhodes and Wiley, 1993 for a regional review). But to drought-stricken regions

of North America, these challenges seemed selfish and overblown. While the growing plight of the US Great Plains and Canadian Prairies drew citizen's and policymaker's attention, it was the emptying of Lakes Powell and Mead (Foti et al., 2012) towards the end of the 2030s and the danger to the Colorado River water regime that sent the nation into crisis over water resources. Depending on one's viewpoint now, the Great Lakes-St. Lawrence River basin could be viewed as a beleaguered system desperately in need of substantial care and restoration or an accessible source of liquid gold.

2043–2053: the center cannot hold

“The failure of the Great Lakes Green Economy can be linked to ignoring greed in the workings of a thriving capitalist economy. This is tantamount to leaving a defenseless lamb in the presence of a starving lion. The environment was consumed as the economy continued to feed off of the natural resources of the Great Lakes region, until we were left with nothing but ashes and dust. In the end, we only have ourselves to blame.”— Cassandra Nova, Prime Minister of Canada, 2045

Over the previous few decades, the general public and political system demonstrated a remarkable ability to normalize increasingly frequent, severe, and even unprecedented natural disasters. However, from 2043 to 2053 fatalistic coping rapidly transitioned into panic. The gravity and intractability of climate change impacts became recognized and understood. Greenhouse gas emissions reached the worst-case scenario projections made by the Intergovernmental Panel on Climate Change half a century ago (Meehl et al., 2007). Perhaps even worse, the influence that these greenhouse gases had on the climate itself proved to be more than was widely considered likely to occur at the time (Hansen et al., 2013). So even when considerations were being made about climate change in the earlier parts of the century, the preparations made for mid-range predictions fell well short of the conditions that emerged (Allison et al., 2009; Rahmstorf et al., 2007; Stroeve et al., 2007). Concerns went unheeded that the pursuit of political and scientific consensus had sacrificed necessary, but less certain, considerations about ice melt, permafrost loss and sea level rise (Brysse et al., 2013; O'Reilly et al., 2012). The corresponding instability in global weather patterns caused transportation infrastructure to crumble and some of the largest economies to deteriorate as international trade waned.

By the early 2040s, the rapid melting and collapse of permafrost throughout the northern latitudes was much better understood. This massive, unstoppable process released large amounts of greenhouse gases that continued to be released for decades to come, locking in further warming never officially considered in the early century's most prominent predictions (Walker, 2007). The effect on the larger global economy was devastating, as the economic impact of even one such methane release from the East Siberian Sea was capable of moving the early 20th century climate change projections forward by 15 to 35 years and resulting in economic damage that was almost equivalent to an entire year of global Gross Domestic Product from the 2010s (Whiteman et al., 2013).

The worst aspect of these events was the new understanding that future impacts were inevitably only going to get more disruptive for generations to come and last for up to 1000 years (Solomon et al., 2009). With environmental and social systems under extreme strain throughout the world and far too few resources to keep track, impacts were no longer felt as a steady worsening of conditions, but were sudden and unpredictable. As the effects of historical increases in greenhouse gas emissions on the global climate were delayed by many years, urgent policy responses were difficult to implement. The result was a widespread sense of despair, manifested as feelings of dread and bitterness among the general public. A citizenry whose values and expectations were still wedded to the promise of prosperity advancements similar to those in the 20th century increasingly suspected, but could not accept, that the future would become worse. One result of this psychological

strain was a growing polarization and fragmentation throughout the Great Lakes region. A cooperation gap paralyzed broader efforts between desperate state and provincial governments and municipal ones. Residents who, for decades, had seen their governing bodies consistently fail to achieve their best interests were becoming more and more cynical about anything other than their immediate community.

These internal forces collided with the external pressures to trade freshwater from the Great Lakes region. As the midcentury point approached, one-third of US counties faced “extreme” or “high” levels of water shortage (Roy et al., 2012). The overwhelming demand on this scarce commodity garnered consensus in the US Congress to end the federal government’s enforcement of the Great Lakes Compact. An attempted block by senators from the region was ineffective, but in reality, the basin had been functioning so poorly as a coherent entity that it was no longer able to defend its own shared self-interest. With each state and countless municipalities struggling to maintain adequate funding and powerful political voices in the region looking to profit off of access to infrastructure and investment royalties, it was only a matter of time before large-scale water export opened up. Attempts were made to develop a regulatory body in order to extract water sustainably, but these efforts quickly became insufficient and then insignificant. Once the US began large scale export, Canada lost its previous hesitancy. Canada had long held back from lucrative water export because, under the North American Free Trade Agreement, once it began making international trade deals, it would have to extend similar offers to the US and Mexico and would have great difficulty reversing any decisions (Heinmiller, 2003). With each additional area that started drawing water from the lakes, the incentive increased to open more areas and expand further before someone else took advantage of the resource first. The Great Lakes had once been a binational example of cooperative management, now they were becoming a large-scale demonstration of the tragedy of the commons (Hardin, 1968) with competing individual interests undermining collective ones. In time, what started as a few opportunities for selective clients became a rapidly growing, competitive extractive industry.

Fears about the dissolution of the Great Lakes Compact had often focused on large-scale diversions, but in reality, export was more influenced by a proliferation of many smaller operations. Building off of the non-bulk industry which had already been growing for the past two decades, larger and more distant transfers were becoming economically viable. Initially, bulk transfer methods such as pipelines were only feasible for areas just outside the basin in the Great Lakes states. But as prices continued to rise, technology improved and desperation increased, expanding the feasible zone of export outwards.

The already-ailing economy and poorly functioning political system made the basin susceptible to the infamous “resource curse” (Auty, 1993; Ross, 1999), where the availability of a valuable extractive resource leads to corruption and a lack of innovation. This results in the power of that industry stifling the political process and limiting diversified economic development. The decision to commodify the Great Lakes region’s water resources was destined to become only more controversial over the years as direct benefactors became entrenched supporters and dissenters lacked formal recourse against this accelerating practice.

2053–2063: the downward spiral

“Guilty? I did what I am accused of, but I am no criminal. The real threats to our society are either in session or in a board meeting today.”—Trey Eliot, Convicted of destruction of property for attempting to destroy a pipeline drawing water from Lake Michigan for trade, 2055

Looking out towards the end of the century is now considered terrifying. Climate change is spiraling out of control, and the social and political responses consist of exploitation, resignation or simply despair. Concerns about keeping global average temperature changes limited to 2 °C (3.6 °F) appear quaint compared to the fear that average

temperatures will likely increase by 6 °C (11 °F) in just a few more decades and continue to rise (Sokolov et al., 2009). While the extent of further warming is still not fully understood, it will be staggering — the last time the Earth had greenhouse gas levels as high as will be reached this century (1000 ppmv +) the polar temperatures rose 20 °C (Kiehl, 2011). Even now, with a 3.5 °C (6.3 °F) increase, over 50% of species are going or will have gone extinct (IPCC, 2007; Fig. 1), all oceanic shell-forming organisms are dying off (Orr et al., 2005), and environmental disruption is rebounding back to civilization in countless, unpredictable ways.

Amidst increasing global pressures, the intensification and expansion of water diversion is further testing the binational relationship between Canada and the US. With many states pulling ever-greater quantities of water from the Great Lakes region, charges of inequitable distribution, poor management and lack of compensation of a shared resource were hurled from Ontario and Quebec to their American neighbors. The Canadian provinces for their part were less dependent on Great Lakes water because many of the north flowing drainage basins to Hudson Bay were tapped and diverted to secure water for the Canadian portion of the Great Lakes basin. This North–South movement of water becomes the model for water security across Canada, as only 38% of Canada’s freshwater supplies are located in parts of the country where almost the entire population of the country lives (Wood, 2013).

The relative water security on the Canadian side of the basin helped ensure a temporary foundation for the region’s continued demographic growth. While Canada has rigorously managed immigration into the region to suit its own interests, the US-side is attracting a large number of the more desperate water migrants from the US Southwest and Great Plains who could not afford to move to the more affluent Pacific Northwest region. Those living around the lakes who have the resources to do so are increasingly isolating themselves in their own protected communities, further polarizing the region’s politics and society. By 2060, a census of the Great Lakes region showed that over 62 million people were living in this heavily-stressed basin (Fig. 1). Poverty is rampant and the cost of public services is ballooning. Not only is the arrival of these climate migrants putting local pressure on water resources, but the mass migration is also encouraging further and further water diversions to raise money and provide other locations for migrants to relocate away from the basin itself.

Political tensions, desperation about the present, and fears about the future are stirring protests, acts of civil disobedience and eco-terrorism. Radical individuals and groups from within the Great Lakes region are sabotaging water pumping stations and pipelines, disrupting the southern and western flow of water. The most extreme of these cases occurred in 2058 when deadly bacteria were intentionally released into a pumping system distributing water to Iowa. Over 50 people were killed and several thousand became ill as a result of the attack. Increasingly vitriolic rhetoric and threats of violence and legal action over previously-signed long-term contracts are setting the stage for yet more destabilization and conflict, thus perpetuating a toxic political cycle through the region and beyond.

Conclusion

This “Out of Control” scenario narrative describes five decades of challenges facing the Great Lakes–St. Lawrence River basin from 2013 to 2063. In it, compounding drivers of change over the last 50 years were met with insufficient planning, funding, and research. The region’s response to the growing set of challenges it faced was short-sighted and focused on narrow interests rather than on developing long-term solutions to shared concerns. All of these conditions fed back into a loop where cooperation became less and less possible even as it was needed more and more. Decades of neglect in the face of disturbing signs of economic and environmental vulnerability set the stage for a rapid unraveling as the region’s environment, economy and society buckled under the pressures of the mid-century. The result was a

complete reversal of the Great Lakes region's fortunes. This region was once known as an economic powerhouse, an environmental jewel, and an innovator in inter-jurisdictional governance. By 2063, it had become a struggling economic backwater, an environmental disaster area, a tense set of wary factions, and an international emblem of humanity's desperate dependence on fossil fuel that came crashing into its even more desperate attempt to deal with the consequences.

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Appendix A. Drivers of Change

Table A1

The state of each driver of change for the Great Lakes region in 2063.

Driver	Description
Aquatic invasive species	A transformed and depleted ecosystem, unrecognizable to those who remember the region of the early 20th Century.
Biological and Chemical Contaminants	Water exporters manage some areas while the rest is poorly managed due to lack of funds and commitment.
Climate change	A more unstable climate than projected and an inevitably bleaker future results in panic and disillusionment.
Demographics and Societal Values	A region overwhelmed by desperate climate refugees not able to relocate to more economically vibrant destinations.
Economy	A weak, extractive resource-dependent economy that has lacked vibrancy and innovation for decades.
Energy	Continued dependence on fossil-fuel extraction has spoiled the region's environment and reputation while restricting investment in other sectors of the economy.
Governance and Geopolitics	A region of factions composed of desperate local governments struggling to survive independently.
Technology	Innovations have served to only enrich the few, put the many out of work and speed up environmental decline.
Water quantity	North America's freshwater bank is draining from export, energy production, and accelerating climate change.

Drivers of change in the year 2063

Aquatic invasive species

Insufficient regulatory efforts and accelerating climate change have tipped the balance of the region's wildlife in favor of invasive species over native ones. Not only have these ecological changes resulted in much less robust and healthy ecosystems, but as aquatic areas have been transformed and made unrecognizable, interest in tourism, recreation and cultural identity have all suffered. The economy has been affected, but the general public's declining interest in protecting the lakes' remaining resources has ultimately been the biggest impact of the spread of invasives in the region.

Biological and chemical contaminants

There has been a consistent failure to close perceived shortcomings in assessment, monitoring and cleanup. As the economy has lagged,

funding has been slashed and cross-jurisdictional cooperation diminished throughout the region. It has become harder to make progress on existing contamination, and the unmanaged impacts of climate change have made the situation even worse. Lower water levels, dredging and stronger weather events have all contributed to more forms of contamination entering into the system. The growing domination of invasive species in the region has made some biological contamination issues worse. Zebra mussels have contributed to anoxic conditions and the spread of *Microcystis aeruginosa*, *Clostridium botulinum*, and fish pathogens; while the Round goby has been a vector for the fish pathogen Viral Hemorrhagic Septicemia Virus (Cornwell et al., in this issue).

Climate change

The mainstream predictions underestimated both how ineffective the world would be at reducing greenhouse gas emissions and how much the climate would change as a result. Climate change has placed tremendous stress on ecosystems, the economy and governing bodies all over the world. The region has been greatly affected by lowered lake levels, droughts, ecosystem upheaval, a reduced global standing due to its involvement in fossil-fuel production and migration into the region of desperate refugees. The predicted future is even worse now, producing panic and despair.

Demographics and societal values

In the early parts of the half-century values shift towards free-market ideals and individual consumption over collective health. After several decades of environmental and economic decline, despair about the future became more and more widespread. The reaction was a further retreat into local and individual interests that has continually damaged the region's resources, identity and world-wide standing. While the population did begin to grow again, it was due to the immigration of desperate climate refugees from both inside and outside North America who were unable to afford relocation to the much more attractive Pacific Northwest and who are now straining the basin's dwindling resources.

Economy

The Green Economy that could have leveraged the resources of the basin and make the Great Lakes region into a vibrant and innovative world leader has now long been only a memory from the early 20th Century. The economy has lurched from one of extractive-resource dependence to another. First it became dependent on supporting of fossil fuel energy development in the form of local natural gas reserves and oil development in Alberta. Later it became a region that drew down its freshwater reserves in the lakes to sell to an ever-expanding area surrounding the basin. The Great Lakes region's long-stagnant economy has only become more constrained by its own over-reliance on these industries for development.

Energy

The region's support of oil sands development to its northwest and the region's own natural gas reserves has grown into a dependence on these industries for economic development. Poor regulation of natural gas fields caused substantial releases of methane, serving as a major source of greenhouse gas emissions whose ramifications are only beginning to be fully understood. By not regulating the expansion of the oil sands, natural gas, and corn-based ethanol industries, there has been widespread terrestrial and aquatic contamination and depleted water resources. Meanwhile, the pursuit of these industries has limited development of greener alternatives in the region, damaging its long-term economic potential.

Governance and geopolitics

Between early multi-national conflict in the Middle East, Pacific tensions with China, and the failure of the worldwide effort to proactively limit the impacts of climate change, the world is in a very fragmented

state geopolitically. Though the Great Lakes basin was a shining example of international cooperation in the early century, it is now representative of a world composed of factions. The region's reduced global standing, along with its own struggles and visible failures of previous cooperative efforts have led to a turn inward where desperate local governments pursue their own short-term interests over the region's.

Water quantity

Water levels are rapidly dropping due to accelerating climate change, the region's longstanding unregulated use of water in fossil-fuel extraction and the now expanding export of water from the basin. This widespread pumping throughout the lake system is demonstrating how even a reservoir of one-fifth of the world's surface freshwater cannot quench a limitless thirst. Receding shorelines have only exacerbated existing tensions between locales that have been unable to share a zero-sum resource and have led to more radical actions by citizens who perceive that their collective resource is being sold off.

Technology

The region consistently leveraged technology to promote short-term economic interests such as resource extraction rather than make the necessary investments in developing emerging industries. Its failure to also adequately support education for cultivating its skilled labor force meant that the emergence of new technologies that could have made the region more attractive for manufacturing such as 3D printing, nano-tech and cognitive computing instead resulted in still more manufacturing job losses. The world has also suffered from the region not taking advantage of its innovative potential, as game-changing climate mitigation technologies failed to emerge.

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