Christopher Kai Tannock

Modernizing Canada's Water Governance: Application of Technology for Current Limitations and Guiding Principles for Progressive Environmental Stewardship

Abstract

In this essay, I focus on the logistical and systemic problems of water management in Canada. There are two components to this essay. The first is to identify the causes of water mismanagement found in the Canada Water Act of 1970. The second part is to give recommendations for renewing the Act given the problematic nature of former legislation. I have identified three causes of management failure, and they are (1) Lack of central data repository, (2) Lack of coordination between political jurisdictions (3) Lack of impact assessment prior to developments. These are broad, encapsulating themes that need comprehensive explanations, which I do in this essay. In the second half of this essay, given the current limitations, I suggest following four themes for updating Canada Water Act. (1) Implementing river basin level management where we can plan transboundary and act locally. (2) Creation of a transboundary data platform where monitoring devices across the country continually collect data using IoT technology and the interested party can access it anytime. (3) Striving for ecological preservation and proactively work on sustainability. (4) Organizing an agency (Canada Water Agency) that oversees the entire water resource management, which is also cofounded by joint engagement between diverse stakeholders. I will explain each suggestion elaborately in the essay. My recommendation is directed towards making Canada's water management more participatory, responsive, sustainable, transparent and adapted to climate change.

1. Introduction

Canada's water governance is at a critical juncture of change in many ways. Canada Water Act of 1970, which was primarily made to respond to the issues raised in the Canada Water Conservation Assistance Act of 1953, is no longer applicable to today's standards.[1] Institutions that study water resource management agree that modernizing the Canada Water Act is necessary[2] , and the creation of a Canada Water Agency that oversees the renewal of the legislation can be thought of as a first step.[3] In this essay, instead of documenting individual

[1] From "Twenty five years of the Canada Water Act" by L.Booth & F.Quinn, 1995, *Canadian Water Resources Journal*, 20(2), 65-90.

[2] From "Water Security for Canadians Solutions for Canada's Emerging Water Crisis" by J.Pomeroy, S.Merrill, C.DeBeer, P.Adapa, et al., 2019, *Global Water Futures*

[3] From "A Canada Water Agency is the first step to modernizing water management" by OM. Brandes, MA.Phare & JW.Pomeroy, 2020, *Policy Options*

cases of water-related issues, I aim to elucidate some of the causes that trigger water management failures. That is because individual cases are the manifestations of a deeply rooted systemic problem, and to give an overall diagnosis and prescription for renewing the Canada Water Act, I need to analyze the causes of the problem and not a symptom. Therefore, the first half of this essay will focus on explaining three causes of water mismanagement in Canada. Nonetheless, I will establish an argument for each cause by discussing actual cases of water-related issues, raising examples from drinking water security, large dam developments and so on. The second half of this essay consists of introducing four themes of recommendations for renewing the legislation.

1.1 Acknowledgement and Focus of this Study

I acknowledge that there are more causes of water issues than I will talk about in this essay. For example, the power relation between indigenous peoples and the federal government of Canada emerging from colonial history results in struggles for indigenous peoples in terms of their infringed water rights.[4] It is an indispensable part of Canada's water management challenge, and their cultural heritage in relation to water should be valued more than now. However, in this essay, I will focus more on the logistical side of the problem and do not dive into the ontological aspect of water management.

2. Three Causes of Water Mismanagement

I have identified three causes of management failure with the Canada Water Act of 1970[5], and they are (1) Lack of central data repository, (2) Lack of coordination between political jurisdictions (3) Lack of impact assessment prior to developments. What they have in common is information mismatch; stakeholders not being able to communicate their needs effectively, managers failing to access relevant information in a timely manner, and impactful decisions being made without a participatory process. I will explain each cause by referring to studies conducted on this topic to eventually think through how these gaps could be filled.

2.1 Lack of central data depository

First, when we analyze what causes water management difficulties, we should hear the voices of water management practitioners and policymakers who work to improve the situation in the

[4] From "Water and Indigenous rights: Mechanism and pathways of recognition, representation, and redistribution" by J.Sue, 2018, Wiley Interdisciplinary Reviews: Water 5 no. 6.

[5] From the section "Part I (Federal-Provincial Arrangement) and Part II (Pollution of Waters, Federal-Provincial Water Quality Management" in Canada Water Act (1985)

frontline. Aggregating and analyzing their concerns could result in forming the basis of an effective solution. And that is what a group of researchers did in their research.[6] The researchers found insightful perspectives on what practitioners and policymakers are feeling in common for not being able to manage water in the most effective ways through large-scale surveys, interviews and a workshop.

According to the report, the foremost concern was the lack of coordination of datasets; practitioners and policymakers all raised strong concern for the lack of "centralized, coordinated, and consistent water-related data".[7] Faced with decisions to make, practitioners and policymakers found it difficult to access relevant information and perform calculations. They do not have an established way to navigate themselves towards the relevant data. One thing to note here is that tools to accumulate and measure data exist in most cases; more than 350 tools to monitor and assess both freshwater quality and quantity have been developed in Canada in the last two decades. Therefore, although First-Nation reserve data is reported to be missing, in general, the ability to collect data is not the root of the issue. Instead, the issue here is that tools and measurements have low transferability between jurisdictions. Existing monitoring and assessment metrics and regulations are fragmented and are not standardized by any means. Such decentralized nature of Canada's water governance has made this situation where practitioners and managers could not find relevant parameters in a timely manner.[8] As a result, water management decisions, which are mostly made locally by provincial and indigenous jurisdictions,[9] are often derived without using a large volume of data nor experts' knowledge, thereby failing to be optimized.

Therefore, there is a gap between the presence of raw data and the availability for usage. The data's utility is limited by the lack of a comprehensive, meaningful and coordinated platform for water management. Moreover, the gap particularly deepens when the responsible water management organization is remote, small and have fewer resources (manpower, fund and experts), as in the case of First Nations communities.[10] I will discuss more later in the essay, but these data problems rising from subsidiarity in water governance can be altogether solved by the establishment of a central data depository and harmonization of measurements,

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[6] From "Recent Developments in Canadian Water Policy: An Emerging Water Security Paradigm," by ES. Norman, K. Bakker, & G. Dunn, 2011, *Canadian Water Resources Journal,* 36(1), 53-66.

[7] From "Recent Developments in Canadian Water Policy: An Emerging Water Security Paradigm," by ES. Norman, K. Bakker, & G. Dunn, 2011, *Canadian Water Resources Journal,* 36(1), 53-66.

[8] From "Harmonization versus subsidiarity in water governance: A review of water governance and legislation in the Canadian provinces and territories," by C. Hill, K. Furlong, K. Bakker, & A. Cohen, 2008, Canadian Water Resources Journal, 33(4), 315-332.

[9] From "Water Security for Canadians Solutions for Canada's Emerging Water Crisis" by J.Pomeroy, S.Merrill, C.DeBeer, P.Adapa, et al., 2019, Global Water Futures

[10] From "Recent Developments in Canadian Water Policy: An Emerging Water Security Paradigm," by ES. Norman, K. Bakker, & G. Dunn, 2011, Canadian Water Resources Journal, 36(1), 53-66.

assessments standards and legislation across jurisdictions. Collected data need to be in the same format and meaningful across Canada so that managers and practitioners could learn from other places.

2.2 Lack of coordination between political jurisdictions

Second theme echoes with what I have just described above in many ways. Lack of coordination between political jurisdictions and highly decentralized water governance in Canada causes various management difficulties and have led to fatal water safety crisis in the past. As I will discuss in this section, Canada's relatively high level of subsidiarity in water management compare to any OECD countries exposes people to water insecurity and download the responsibility of providing safe water to the lowest level of public authority.[11]

As I noted earlier, under current decentralized governance, each jurisdiction tends to develop monitoring and assessment tools within its jurisdictional boundaries with very little sharing. As a result, highly diverse and fragmented legislation and policies for water management have developed across Canada.[12] Especially, a high degree of fragmentation is seen among drinking water protection, watershed governance, water rights, water exports, and transfers.[13] This is problematic for many reasons, largely due to the fugitive but essential-to-life nature of water resources, and each topic needs elaborate explanations on why fragmentation hinders effective water management capacities.[14] In this essay, I want to shed light on drinking water governance because it is highly interconnected to human activities, and people will see dire consequences on health if not appropriately managed, unlike other topics.

Several fatal drinking water outbreaks happened in the recent history of Canada, and I analyzed three of those cases (table 1): Drumheller (Alberta) in 1983, Walkerton (Ontario) in 2000, and North Battleford (Saskatchewan) in 2001.[15] I have found few things in common that caused these incidents, and they are intimately related or mirror the three causes of water

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[11] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

[12] From "Harmonization versus subsidiarity in water governance: A review of water governance and legislation in the canadian provinces and territories," by C. Hill, K. Furlong, K. Bakker, & A. Cohen, 2008, *Canadian Water Resources Journal*, 33(4), 315-332.

[13] From "Harmonization versus subsidiarity in water governance: A review of water governance and legislation in the canadian provinces and territories," by C. Hill, K. Furlong, K. Bakker, & A. Cohen, 2008, *Canadian Water Resources Journal*, 33(4), 315-332.

[14] From "Water governance in Canada: Innovation and fragmentation," by K.Bakker & C.Cook, 2011, *Int J Water Res Dev*, 27(2):275-289

[15] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

mismanagement I raised in the beginning. The common causes of these fatal drinking water crises are (1) lack of coordination between political jurisdictions, (2) the inability to respond in real-time, and (3) failure of risk management. Moreover, analyzing these incidents illuminated the need for IoT devices that report municipal water quality continuously to the centralized data center where they monitor and ensure water safety at any given time.

	Year	Town size (population)	Number of infections	Deaths	Disease	Causes
Drumheller	1983	6500	3000	2	Gastroenteritis	A spill of raw sewage upstream of the town's drinking water intake (water source contamination) is the cause.
Walkerton	2000	2000	2300	7	Gastroenteritis	Shallow well being contaminated by cattle manure following heavy spring rainfall and widespread flooding.
North Battleford	2001	15000	5800-7000	3	Cryptosporidium	Water treatment plant intake was located 3km downstream from the city's sewage treatment outfall.

(Table 1)[16]

First, fatal drinking water outbreaks all occurred in small size towns where their water treatment plant operator was inadequately trained to detect water contamination. North Battleford incident happened after the former operator took retirement and replaced by a less experienced operator, which resulted in negligible fine particle removal, only relying on chlorination to disinfect the water. As chlorination is not effective at preventing Cryptosporidium, the incident took place, costing three lives.[17] Only if there had been a centralized data center that detects water contamination across political jurisdictions, these problems emerging from the lack of resources could be prevented. Hrudey states that these water contamination incidents took place as a result of "complacency and lack of operational and regulatory competence for entire system"[18]; these water crises emerged not just from the failure of the municipal level managers and operators, but by series of failures by provincial regulators and federal government; decentralized and fragmented water governance laid the foundation for water crisis to take place.

The second point they have in common is the inability to respond in real-time. In these incidents, the detection of contaminants was essentially first reported by doctors who saw hundreds of people getting sick in the region at the same time. Reaction from municipal operators happened only after mass infections had taken place - this is too late. We want to close the time lag between detection and reaction as much as possible for drinking water governance to reduce the risk of infections. In the early 2000s, it was impossible to monitor and report water quality 24hrs to responsible decision-makers; however, as of 2021, it is now possible using IoT technology; measuring real-time water quality parameters (such as turbidity,

[16] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

[17] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

[18] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

chlorine residual, pH, conductivity, UV absorbance, trihalomethanes level and many other[19]) and reporting them continually become available for the first time. We could notice the contamination long before the mass infection happened if water quality and relevant parameters had been sent to a centralized data center. The data center could then warn the municipality not to use the water until safety is guaranteed. Furthermore, in the face of climate change, the water management challenges are accentuated, demanding us to respond timely and optimally, as well as needing to predict water quantity due to distributional change in precipitation.[20] I will discuss more using IoT as a key monitoring system for water management in the later chapter, but the inability to respond in real-time is the major constrain we have today for water security in Canada.

The third point they have in common is the failure of risk management. In all cases, contamination potential was perceived and foreseeable; nonetheless, the managers failed to place a proactive measurement. For example, in Walkerton, the shallow well that became the source of contamination had been identified as vulnerable to agricultural contamination by the hydrologist who installed the well in 1978.[21] However, local managers did not fully appreciate his warning, and as a result, caused one of the most severe water contamination accidents in Canada's history. The same thing applies to North Battleford, where provincial regulators knew for almost 40 years that the proximity of water treatment plant intake and sewage treatment outfall is a chronic risk but finally did not take action before it was too late. In explaining these phenomena, solely blaming the complacency of local water resource managers is far from appropriate; rather, Canada's systemic nature of delegating the responsibility of providing safe drinking water to the lowest level of public authority is the issue.[22] Local municipalities often lack access to funding and human resources necessary for planning and implementing safer measures. For these reasons, in most cases, municipal governance can only be *reactive* in the face of threats at best and not *preventive*.[23] These incidents all happened 20 years ago and beyond; however, the nature of these issues or the reasons that caused these water crises are largely unaddressed, meaning another Walkerton water poison accident could take place any

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[19] From "Water policy in Canada: problems and possible solutions" by MH., 2015, *Earth and Environmental Science*.

[20] From "Water Security for Canadians Solutions for Canada's Emerging Water Crisis" by J.Pomeroy, S.Merrill, C.DeBeer, P.Adapa, et al., 2019, *Global Water Futures*

[21] From "Safe drinking water policy for Canada turning hindsight into foresight" by SE. Hrudey, Howe Institute, 2011.

[22] From "Drinking water management and governance in Canada: An innovative plan-do-check-act framework for a safe drinking water supply" by T.Bereskie, MJ.Rodriguez, R.Sadiq, 2017, *Environmental Management*, 60(2), 243-262.

[23]From "Drinking water management and governance in Canada: An innovative plan-do-check-act framework for a safe drinking water supply" by T.Bereskie, MJ.Rodriguez, R.Sadiq, 2017, Environmental Management, 60(2), 243-262.

time, especially in the small municipalities. Also, climate change increases the probability of flooding, increasing the risk of another water-borne disease outbreak.

Therefore, for Canada's water security, the Federal government, which can fund resources and currently responsible of delivering safe drinking water to small municipalities (primarily First nations communities)[24], should be more connected to municipal predicaments and think together an optimal solution for preventive measures. Improvement of coordination between political jurisdictions is imperative, especially when we consider how many people are served by a small drinking water supply system in Canada. More than 60% of people in Canada are served by a drinking water system that is designed only to provide water for less than 500 people, and almost 80% of the population is served by a small drinking water supply system (fig.1). [25] Therefore, under the current fragmented water governance based on subsidiarity and lack of centralized intelligent monitoring system, 80% of the population are at risk of facing another fatal drinking water crisis.

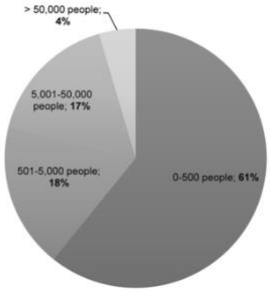

Fig.1 Drinking water system in Canada, by population served[26]

2.3 Lack of impact assessment (social and environmental considerations) prior to developments

Partly in relation to what I have described above about the identified risk and the neglect, the Canada Water Act of 1970 has a limited scope of impact assessment for proposed projects[27], and it fails to analyze alternative options. Under the current legislation, the project's impact is

[24] From "Chapter 4: Safety of Drinking Water: Federal Responsibilities" in the Report of thee Commissioner of the Environment and Sustainable Development

[25]From "Drinking water management and governance in Canada: An innovative plan-do-check-act framework for a safe drinking water supply" by T.Bereskie, MJ.Rodriguez, R.Sadiq, 2017, *Environmental Management*, 60(2), 243-262.

[26] From "Drinking water management and governance in Canada: An innovative plan-do-check-act framework for a safe drinking water supply" by T.Bereskie, MJ.Rodriguez, R.Sadiq, 2017, Environmental Management, 60(2), 243-262.

[27] From the section "Part III (Regulations) and Part IV (General)" of Canada Water Act 1970

only considered after planning had happened or commitment to development had been made.[28] Its scope is heavily leaning towards engineering aspects of the project, and at its best, rather a complete avoidance, it only encourages mitigating some of the project's adverse impacts.[29] Instead of the current approach, we need to think more about the "alternative to" option before proceeding to large-scale development. Otherwise, we will learn only with hindsight that it is more costly to proceed with project developments in haste than to critically assess them with alternative options. The recent development of the Site C dam best exemplifies such a case.

The reason to reconsider Site C dam construction is apparent when we analyze its environmental impacts, economic risks, and employment benefits. Researchers at UBC Water Governance reviewed impacts of Site C comprehensively across different dimensions, and they summarize its environmental impact as the worst in 25 years of environmental impact assessment. They state that "Site C has the most significant adverse environmental effects than any other project ever assessed during the 25-year history of the Canadian Environmental Assessment Act".[30] Therefore, Site C is recognized to have a substantial negative impact on the environment even compare to some of the most notorious developments, such as oil sands projects. This unpreceded impact of Site C on the environment is partly from disrupting the pristine Peace River Valley's biodiversity and damaging the UNESCO heritage site (Buffalo National Park) as downstream impacts. Also, First Nations' land use and cultural loss worsened the portfolio. Moreover, Site C does not reduce greenhouse gas emissions; in fact, it will increase the emissions by amplifying the decomposition of organic matter.[31] Economically, much of the energy from Site C will be exported at a loss (export price < cost of production) because BC Hydro is overestimating the energy demand. Currently, the project is over budget and delayed for completion, further lowering the profitability and threatening to increase the electricity bill for people in BC.[32]

If CEAA 2012 and Canada Water Act had designed to enforce project proponents to assess alternative options in-depth when they plan to develop large dams, we would have realized that other renewable energies such as geothermal and winds were more desirable options for people and the environment. Geothermal and winds had been cheaper than Site C,

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[28] From the section "Part II (Pollution of Waters) and Part IV (Public Information Program)" of Canada Water Act 1970

[29] From "25 years of Canada Water Act," by L.Booth & F.Quinn, 1995, *Canadian Water Resources Journal*, 20:2, 65-90

[30] From "Site C: Summary of Key Research Results" by R.Hendriks, P.Raphals, K.Bakker, 2017, *Program on Water Governance*, University of British Columbia: Vancouver

[31] From "Site C: Summary of Key Research Results" by R.Hendriks, P.Raphals, K.Bakker, 2017, *Program on Water Governance*, University of British Columbia: Vancouver

[32] From "Cost of Site C dam spiralling amid construction challenges, says open letter urging halt to project" by A.Ross, 2020, CBC News

emitted lower greenhouse gas, contributed to employing three times more people, and would have avoided impacting indigenous peoples.[33] Therefore, it is unfortunate that Site C was rushed to proceed with construction without delivering enough environmental and societal considerations beforehand and not implementing the "alternative to" option. We should make the Canada Water Act in a way that the legislation becomes the barrier against shortsighted project development. Also, if Canada Water Act had played such a role from the beginning, maybe the outbreak of the water-borne disease in North Battleford would not have taken place because the Act would forbid to construct water treatment plant proximate to the sewage treatment outfall; that kind of shortsightedness would have been revoked under such legislation.

In truth, Site C was designed to expand the oil and gas extraction in Mackenzie Basin. The electricity generated in Site C will be used not by people in BC but by the oil industry in North Eastern BC and Alberta. That is ethically controversial, and it brings us to another discussion on the sustainability of water resources. Normative statements on what Canada should do towards reducing greenhouse gas emissions and what role Canada should play in the global landscape of water governance for sustainability need to be made upon renewing Canada Water Act. I will discuss this topic more in the following second half of the essay.

3. Themes of Recommendations: IoT based Water Management

So far, I have demonstrated the flaws of current legislation and raised examples of water mismanagement that evolved from problematic governance. In doing so, I suggested some ideas that would prevent us from making the same mistakes, such as harmonization of measures, improvement in data access, the need for an intelligent centralized water data headquarter, and the robust role of the legislation for developments. I will further elaborate upon these suggestions while synthesizing them in the remaining part of this essay.

I think to modernize Canada's water management, what we need as encapsulating vision is the enhanced connection between people and water. People should be more connected with the physical reality of water, and also, water should be managed by understanding the realm of socio-hydrology and hydro-social cycle more[34]. What embodies this vision into reality is IoT-based water management. The ability to sense various water parameters and to communicate them in real-time will be a powerful tool for Canada's water security. More specifically, IoT-based water management will enable three key practices for sustainable water governance: (1) Implementing river basin level management where we can plan transboundary and act locally. (2) Creating the open water data platform to collect scattered data and increase sharing of data. (3) Being able to be proactive for sustainability and to strive for ecological

[33] From "British Columbia Utilities Commission Inquiry Respecting Site C", 2017, *BCUC*, Final Report to the Government of British Columbia, Appendix C.

[34] From "The hydrosocial cycle" by J. Budds, J.Linton & R. McDonnell, 2014, Geoforum, 57(57), 167-169

preservation. I will explain the detail of IoT-based water management in parallel with these three key recommendations.

Fig 2. The Internet of Things for Sustainable Water[35]

3.1 Implementing river basin level management

In this section, I want to go over what I envision in IoT-based water management and explain its advantages on across-the-board management. First, ideal water management covers the whole water cycle, and the inclusion of human interference is indispensable. As we can see in diagram 1, human interference to the water cycle is substantial and impact the environment in many ways. For example, agricultural runoff that contains an abnormal amount of nutrients for the aquatic environment causes eutrophication, where algae-bloom produces hypoxia and destroys the aquatic ecosystem. Globally, eutrophication-induced hypoxia accounts for roughly half of all "dead zones" in the world's ocean, and Canada is responsible as well.[36] Moreover, dams, urbanization, surface water intake, and many other human activities that interfere with the water cycle impact aquatic ecosystems and beyond. By sporadically installing IoT monitoring systems from upstream to downstream, we can understand where contaminants enter and how much. That way, the regulators can identify polluters, and necessary measures can be taken to improve the condition, hence being able to manage water resource transboundary and acting locally.

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[35] From "Chapter 4: Internet of Things for Water Sustainability" in Internet of Things for Sustainable Community Development by A.Salam, 2020, *Internet of Things (Technology, Communications and Computing)*, Springer

[36] From "Spreading Dead Zones and Consequneces for Marine Ecosystems" by Robert J.Diaz and Rutger Rosenburg, 2008, *Science*, 926

It is technologically possible as methods to connect sensing devices to IoT and monitor important parameters in real-time are already developed: pH sensing, conductivity sensing, dissolved oxygen sensing, eutrophication and nutrient sensing, water flows sensing, and temperature sensing can be connected to IoT.[37] Moreover, continually collecting the source water data contribute to building the baseline environmental information that is missing now and hindering the decision-making ability.[38]

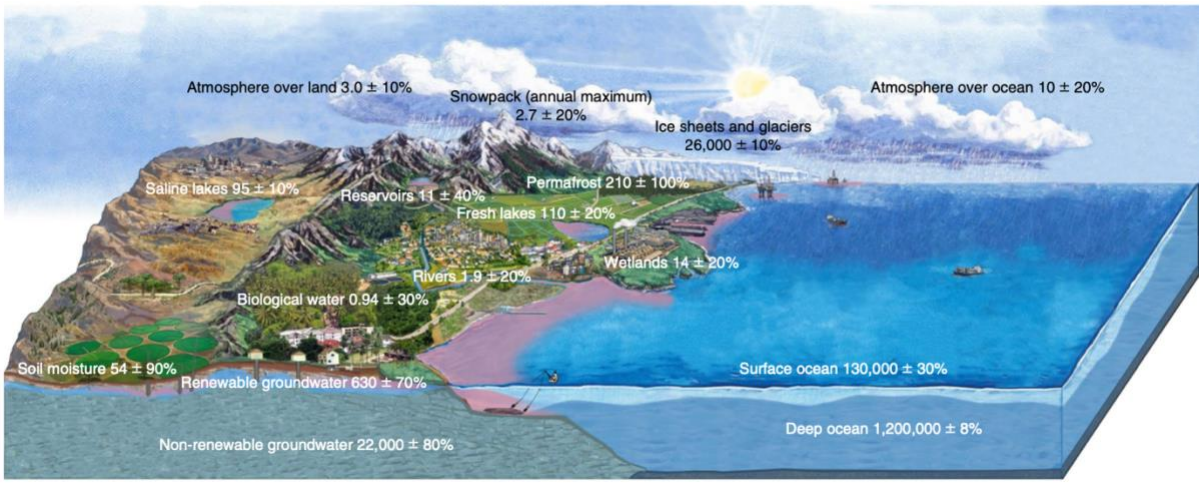

Diagram 1.) Global hydrological cycle in the Anthropocene (major water pools expressed in $10^3 km^3$, human pollutants represented with pink shading)

Not only source water information for better understanding human impact on water, but a wide range of information from various sectors of water management will be available with extensive IoT sensors and monitoring devices, and importantly, they can produce values by enabling us to make use of untapped resources. For example, suppose we install IoT monitors to measure the amount of organic matter in the wastewater. Then, we will have a better sense of how much organic matter is in the wastewater. In turn, that information can be used to finance biogas or bioplastic plants operated by recovered organic matter from the city's wastewater, as in the case of Amsterdam.[39] Not only wastewater contains organic matter, but many types of chemicals are diluted in the wastewater by various human activities, such as pharmaceutical chemicals. IoT-based water management would help to recover these resources from the wastewater.

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[37] From "Chapter 4: Internet of Things for Water Sustainability" in Internet of Things for Sustainable Community Development by A.Salam, 2020, *Internet of Things (Technology, Communications and Computing)*, Springer

[38] From "Recent Developments in Canadian Water Policy: An Emerging Water Security Paradigm," by ES. Norman, K. Bakker, & G. Dunn, 2011, *Canadian Water Resources Journal*, 36(1), 53-66.

[39] From "Wastewater as a resource: Strategies to recover resources from Amsterdam's wastewater" by JP. van der Hoeka, H. de Fooija, & A. Strukera

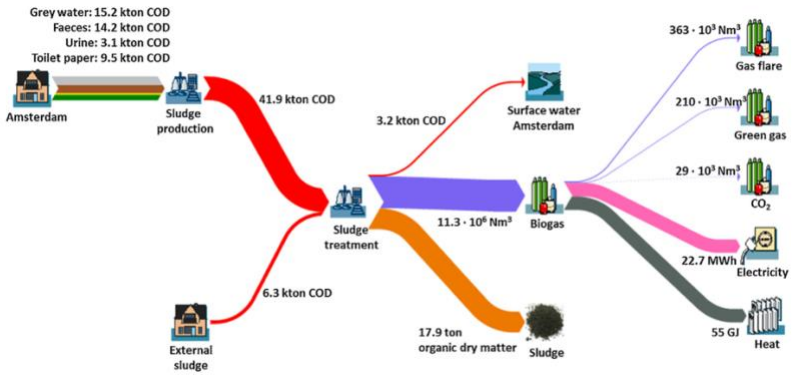

Fig.2 Organic Matter in Amsterdam's wastewater chain 2013[40]

3.2 Creating the open water data platform to collect scattered data and increase sharing of data

The next thing we need is the creation of a transboundary data platform where IoT monitoring devices across the country continually collect and submit data and where interested parties can access it anytime. A pilot model for this system is launched in the United States by Advisory Committee on Water Information. It is designed to integrate water information to open data web for data sharing purposes.[41] That kind of data platform will revolutionize the transparency of water resource management and ignite entrepreneurial efforts to improve water management. For example, Kamienski et al. envision IoT-based precision irrigation to avoid under and over-irrigation[42]. In the pilot projects in Brazil, they have managed to get the same yield with about 30% of water usage. Even compared to a high-efficiency method like drip irrigation, IoT-based water irrigation scored higher on water conservation.[43] It is highly relevant to Canada, where irrigation is a significant part of farming where farms using 109,128 cubic meters of water irrigation annually on average. Also, the savings of consumed water can be substantial as agriculture as a whole consumed 1600 million cubic meters of water in 2013, representing approximately 45% of all consumed water in Canada that year.[44] Another entrepreneurial breakthrough that would be possible with the across-the-board platform is remote health hazard

[40] From "Wastewater as a resource: Strategies to recover resources from Amsterdam's wastewater" by JP. van der Hoeka, H. de Fooija, & A. Strukera

[41] From Water Information Coordination Program by Advisory Committee on Water Information

[42] From "Smart Water Management Platform: IoT-based Precision Irrigation for Agriculture" by C.Kamienski, JP. Soininen et al., 2019, *Sensors*

[43] From "Smart Water Management Platform: IoT-based Precision Irrigation for Agriculture" by C.Kamienski, JP. Soininen et al., 2019, *Sensors*

[44] From "Water withdraw and consumption by sector" by Government of Canada, 2013

alarm. If real-time data on water quality and quantity are available, services that provide additional resources for small municipalities will be possible. That will strengthen Canada's water security and reduce the inequality between cities and rural areas for water safety.

3.3 Being proactive for sustainability and ecological preservation

In the face of climate change and global environmental destruction[45], I think Canada has the responsibility of being a world leader for water sustainability. In doing so, I believe Canada Water Act should be designed to go beyond "status quo sustainability" and aspired to accomplish "regenerative sustainability"; instead of emphasizing harm reduction and damage limitation, thinking and applying ways to rehabilitate and restore the ecosystem while delivering safe water for all people at the same time.[46] There are two ways of making a human impact a "Net Positive" for the environment[47,48,49] :one is compensatory mitigation, which is often taken by corporate sectors[50] , and the other is what I call a "satoyama design".

Compensatory mitigation is essentially an offset scheme where the project proponent uses accounting to calculate the net impact of a project and compensate for the damage by investing in conservation efforts remotely or onsite.[51] Therefore, when project proponents over-compensate, the project will be considered to be an "net positive" project. These approaches are primarily taken by companies in the oil, mineral and energy industry,[52] BC Hydro is one of them, and their goal is to achieve "no net incremental environment impact."[53] Although compensatory mitigation seems a pragmatic approach to offset the impact of

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[45] From "A Safe Operating Space for Humanity" by Johan Rockstrom et al., 2009, *Nature*

[46] From "Theoretical underpinnings of regenerative sustainability" by J. Robinson & RJ. Cole,

[47] From "Biodiversity offsetting and net positive design" by J.Birkeland & S.Knight-Lenihan, 2016, *Journal of Urban Design*

[48] From "Surpassing sustainability: making a 'net-positive' impact" by S.Rahimifard & H.Trollman, 2017, *International Journal of Sustainable Engineering*

[49] From "Net positive outcomes for nature." by Bull et al., 2019, *Nature Ecology & Evolution*

[50] From "A review of corporate goals of no net loss and net positive impact on biodiversity" by Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., & Pilgrim, J. D., 2015, *Oryx*

[51] From "Guidance Notes to the Standard on Biodiversity Offsets" by Business and Biodiversity Offsets Programme.

[52] From "A review of corporate goals of no net loss and net positive impact on biodiversity" by Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., & Pilgrim, J. D., 2015, *Oryx*

[53] From "Climate Change and Environmental Impact" by BC Hydro

development[54], it is problematic for a number of reasons, and I suggest compensatory mitigation not to be the primary method for achieving Net Positive water governance. One of the reasons is that compensatory mitigation can only be adopted by industries that have high net economic profits per area.[55] Water governance should not be profitability driven, so it is unlikely to gain more than enough margin than operation and sustenance cost, hence investment towards environmental conservation on the side is unachievable. What they do in the mining and oil industries is not replicable in water governance.

Instead of leaving negative impacts as they are and investing in other conservation projects as a form of compensation, water governance should be aspired to be Net Positive by implementing the other approach - Satoyama design. Satoyama is referred to as a socio-ecological production landscape that developed in Japan, and it entails a harmonious relationship between nature and humans. Satoyama Initiative's founder defines Satoyama as the "dynamic mosaics of habitats and land uses that have been shaped over the years by the interaction between people and nature in ways that maintain biodiversity and provide humans with goods and services needed for their well-being."[56] Therefore, the principle of Satoyama is to host biodiversity in the context of human presence and turning the presence of humans into an integral part of the ecosystem. For example, properly managing forests by human hands enhance the ecosystem services more than when we leave them alone.[57] Thus, if we extrapolate Satoyama design, it means that humans can be good for the ecosystem. That is powerful and revolutionary. Yet, it is so hard to imagine and perhaps sound overly optimistic. Nonetheless, it is clear that that is the vision we should be aspired to head for our Canada's water governance, and these values should be incorporated in the update of Canada Water Act.

Furthermore, Satoyama design is highly relevant to Canada because it relates to reclaiming the culture and lives of indigenous peoples that is described in Bill C-15.[58] The idea of illuminating or segregating people from the natural landscape is inherently the best way for the conservation of nature is a western value, and it resulted in fragmenting the traditional life of indigenous peoples and the landscape that co-evolved with them.[59] Satoyama design would

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[54] From "Three ways to deliver a net positive impact with biodiversity offsets." By A.Moilanen & JS.Kotiaho, 2021, *Conservation Biology*

[55] From "A review of corporate goals of no net loss and net positive impact on biodiversity" by Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., & Pilgrim, J. D., 2015, *Oryx*

[56] From "Rebuilding the relationship between people and nature: the Satoyama Initiative" by K.Takeuchi, 2010, *Ecological Research*

[57] From "Greetings from Satoyama" by K.Takeuschi, 2009, *United Nations Univeristy*

[58] From "An Act respecting the United Nations Declaration on the Rights of Indigenous Peoples" (Bill C-15), 2020, House of Commons of Canada

[59] From "Respecting water: Indigenous water governance, ontologies, and the politics of kinship on the ground" by N.J.Wilson & J.Inkster, 2018, *Environment and Planning E: Nature and Space*

encourage people and the culture to be a part of the ecosystem again; benefitting people and nature. When modernizing Canada Water Act, we should have an overarching vision that may not necessarily be achievable in our lifetime but based on long-lasting, thriving value. And I think that the vision should consist of these elements that start with understanding the ecosystem as a dynamic process and conceptualizing humans to be a part of the system - never an authority but a facilitator for vitality.

IoT-based water management necessarily has to be a part of regenerative sustainability or satoyama design for water governance. Building a large data pool for the aquatic environment contributes to understanding the dynamic process of the ecosystem and enables to identify solutions for improvements on a case by case. Especially in the face of climate change, biodiversity conservation may involve more than just leaving physical space for other species, but appropriate human involvement, including greener urban design[60], seasonal water consumption limit, afforestation and many other activities, may become necessary. Being able to analyze the work of ecology with Big Data would improve our approach to ecological conservation.

3.4 Organizing Canada Water Agency

Lastly, Canada Water Agency (CWA) should be established to manage data platforms and to transcend water governance over constitutional division of powers. This suggestion aligns with the statement issued by the Government where they state CWA to "work together with the provinces, territories, Indigenous communities, local authorities, scientists and others to find the best ways to keep our water safe, clean and well-managed."[61] To effectively achieve that goal, I think CWA needs to be independent of any government or institutions so that their decisions will be free from bias but be as fair and competent as possible. Also, CWA should be cofounded by members from diverse backgrounds: federal government, provincials, representatives of local authorities, indigenous nations and scientists, to be able to perform water governance across jurisdictions dictions with equity and inclusivity. This type of governance support system that is based on multi-stakeholder dialogue and transboundary collaboration is implemented by World Commission on Dams (WCD).[62] However, WCD has been referred to as a manifestation of global corporatism and criticized that the consultations do not result in enforceable policy, thereby lacking effectuality.[63] CWA should acknowledge

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[60] From "Framework for net-zero and net-positive building water cycle management." by CM.Joustra & DH. Yeh, 2015, *The International Journal of Research, Development and Demonstration.*

[61] From "Towards the Creation of a Canada Water Agency" by Environment and Climate Change Canada, 2019

[62] From "Debating dams: The World Commission on Dams 20 years on" by C.Schulz, W.M.Adams, 2019, *Wires Water*

[63] From "Corporatism goes global: International organizations, nongovernmental organization networks, and transnational business" by M.Ottaway, 2001, *Global Governance*

these criticisms and be founded to gain stronger legitimacy and designing ways that can leverage the decision-making process more.

CWA should be the bridge between local authorities, provinces, the federal government, and indigenous nations for overall decision-making processes. Although the responsibility of water management is assigned to federal, provincial and indigenous governments for different purposes now[64], holistic watershed management should take place, and CWA should take on that role. For example, the federal government is responsible for pollution prevention of freshwater while the provincial government, as well as local authorities, are responsible for drinking water, aquatic environment management and wastewater services. All these topics are intimately interconnected; however, there is a jurisdictional gap[65]; CWA should be there to promote multilateral engagement and coordination. Small municipalities would particularly benefit from such a system.

In conclusion, modernizing Canada's water governance involves reflecting back to problems that occurred under the current Canada Water Act 1970 and thinking of ways in which we can avoid making the same mistakes; not only that, but new legislation also needs to take on the responsibility of sustainably managing water for all people and biodiversity. Moreover, it has to guide Canada's water governance towards adapting to climate change. This essay has discussed some of the ways and values that gear us in the right direction.

[64] From "Toward the Creation of a Canada Water Agency" by Environment and Climate Change Canada, 2019

[65] From "Toward the Creation of a Canada Water Agency" by Environment and Climate Change Canada, 2019

Christopher Kai Tannock

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