# Building the Capacity for Watershed Governance

by

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**Abstract**

BC Hydro's Water Use Planning (WUP) process is one of the world's most comprehensive hydroelectric dam operational reviews and has served as a model to revise hydropower operating plans with the participation of an inclusive range of stakeholders, rights holders, and the use of up-to-date scientific information, that meets social and environmental goals alongside economic targets. In 2000, BC Hydro initiated a WUP process in the Jordan River watershed. This watershed hosts a wide diversity of water users, including active resource industry stakeholders (mining, forestry, and hydropower), Indigenous rights holders, and rural community citizens; which is representative of watersheds in British Columbia with established WUPs. BC Hydro finalized the Jordan River WUP in 2003, which focuses on establishing critical freshwater flows for fish habitat and achieving specific recreational values of the local community. However, numerous other issues still remain that were beyond the scope of the WUP process, including water quality concerns that were continually brought up by citizens during the consultative process of the WUP. In addition to these concerns, biological monitoring following the implementation of the WUP suggests that contamination from an inactive copper mine has affected and altered sensitive water quality parameters for a healthy Pacific salmon habitat in Jordan River. Yet, there has not been an extensive water quality study conducted that examines the spatial or seasonal water quality extents of the mining contamination in Jordan River, specifically copper. Consequently, fourteen years after the creation of the WUP, local advocates are still struggling to have their concerns heard by the entity responsible for freshwater flow, BC Hydro, alongside federal and provincial government agencies. Advocates are calling for the creation of a watershed-based group as a mechanism for having greater influence in water planning and governance processes. This study explores the research question: if and how has the WUP process contributed to creating watershed governance capacity? This social science thesis project employs a mixed-methods approach using both quantitative and qualitative data. The study includes a document review of relevant water governance literature and focuses on examining the freshwater quality of the Jordan River. Water quality samples were collected over a five-week period from five sites on the Jordan River beginning in September and concluding in October of 2015 during the most sensitive periods of salmon spawning activity in the lower reaches of the Jordan River. Spatial and seasonal water quality trends were identified, and analysis concluded that copper is the primary contaminate affecting the productivity of a healthy salmon habitat in the Jordan River. Acid mine drainage (AMD) processes were identified throughout the water quality data and are strongly influenced by the proximity of existing mine waste piles sourced from an abandoned copper mine, and unnatural anthropogenic flows from the three BC Hydro dams present in the Jordan River system. The final stage of the research project focuses on assessing the adaptive capacity in the watershed to address the issues of concern outlined in the WUP. There is a current movement to create watershed organizations that are formally supported through new legislation in British Columbia, but questions remain about the capacities of these watershed communities to sustain such a formal institution and if these watershed communities are ready to successfully implement a local watershed governance model. The Gupta et al. (2010) six adaptive capacity dimensions provide a logical framework to explore if these capacities are present such that it could be expected that local watershed organizations would be effective as society adapts to more watershed-based governance approaches. Thirteen semi-structured interviews were conducted from October 2016 to February 2017. Interviews and observational data focused on the WUP process and prospective and current members of the Jordan Watershed Round Table (JWRT). The research evaluated whether these six adaptive capacity dimensions are present in watershed communities that have been subjected to water management processes, specifically the WUP program. Overall, the research concluded that the WUP has contributed to some adaptive capacity for watershed governance in the Jordan River, specifically on building the adaptive capacity dimensions: variety, learning capacity, room for autonomous change, leadership, and resources within the JWRT.

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# Chapter One

## Introduction

In Canada, freshwater has been traditionally viewed as an infinite resource and consequently, mismanagement has followed (Brandes, Brooks, & M'Gonigle, 2007). Canadians have become masters at intervening with hydrological regimes and manipulating landscapes to conveniently suit the demands of a growing society that fuels a thriving economy (Brandes & O'Riordan, 2014; Walkem, 2007). Canada's freshwater resources are managed on the basis of abundance in *water supply*, which is a function of the depressions that hold water within the landscape (Sprague 2007). The volume of Canada's water supply overall contributes to 20% of Earth's freshwater lakes, where 18% rests in the Great Lakes (Mitchell, 2017; Sprague, 2007). Canada's water supply is sourced from thousands of years of glacial retreat (Bakker, 2007b; Nowlan, 2007; Sprague, 2007). Glaciers referred to by scholars as 'water towers', are rapidly disappearing from mountaintops and no longer replenishing freshwater supply sources (Messerli, Viviroli, & Weingartner, 2004; Viviroli, Dürr, Messerli, Meybeck, & Weingartner, 2007). Since 1850, over 1300 glaciers have reduced their mass by 25-75% in Canada (Nowlan, 2007) with most of the reduction occurring in the last 50 years as a result of global climate change (Messerli et al., 2004). The *renewable supply* is considerably different than water supply and includes precipitation and freshwater runoff that flows along the contours of the land into catchment basins replenishing water supply sources at varied locations annually (Sprague, 2007). For example, the renewable supply of the total volume in the Great Lakes is a mere 1% each year (Schindler, 2007). Climate change is expected to exacerbate water issues in Canada and will not only affect the quantity of freshwater, but the quality as well (Bakker & Cook, 2011; Brandes & O'Riordan, 2014; Lautze, De Silva, Giordano, & Sanford, 2011; Shrubsole & Draper, 2007). Excess freshwater plays an important role in stabilizing water quality by diluting contaminants and minerals in freshwater sources (Bakker & Cook, 2011; Brandes & O'Riordan, 2014; Lautze et al., 2011). Furthermore, freshwater resources are unequally distributed across the landscape. A unique aspect of Canada's geography is that 60% of the available fresh water flows north to the Arctic Ocean away from 85% of Canada's total population who live along the southern border (Bakker & Cook, 2011; De Loe & Kreutziser, 2007; Schindler, 2007; Sprague, 2007). Currently, Canada ranks third in the world's annual renewable supply at 6.5% and is tied with China and the United States (Sprague, 2007; World Resources Institute, 2003); however, when all variables are considered with the 40% of fresh water available to the majority of the population in the South, then the accurate total would be 2.6% of the annual renewable supply. If 2.6% of accessible fresh water is renewed each year for 85% of the total population of Canada, then Canada would fall in rank to ninth place in the world's renewable supply between India (2.9 %) and Democratic Republic of Congo (2.1 %) (World Resources Institute, 2003). Overall, the misconception of Canada's freshwater abundance needs to be carefully considered in water resource decisions.

Canada's water crisis is said not to be one of scarcity, but of *water governance* (Brandes et al., 2007; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Lautze et al., 2011). Water governance is defined as the processes and institutions through which water-related decisions are made (Lautze et al., 2011; Reed & Bruyneel, 2010). The distribution of power and authority is expanded horizontally across jurisdictions and defined at multiple vertical scales of governance (Bakker, 2007b; Reed & Bruyneel, 2010). It is distinct from *water management,* which focuses on the operational and technical aspects of water with largely defined outcomes and prescriptive measures (Bakker & Cook, 2011; Lautze et al., 2011; Reed & Bruyneel, 2010). Water governance seeks to define the goals of water management and align practices with desired outcomes by providing a framework that links planning to implementation (Lautze et al., 2011). A well-established governance framework is imperative to defining water management goals within a watershed (Lautze et al., 2011).

In many watersheds across Canada and specifically in British Columbia, there are intensive resource extraction activities that have occurred in the recent past, and no longer continue. For instance, in some watersheds mines have halted operations, or forestry activities such as logging are no longer active (Barry, Grout, Levings, Nidle, & Piercey, 2000; Hunter, Brandes, & Moore, 2014). While negative impacts of resource extraction on water quality and quantity are well-documented, these prosperous economic activities often remain high risk and can severely impact the sustainability of water resources even after the activity itself is no longer occurring. While many studies examine the water quality issues related to resource extraction activity while they are occurring (Bhuiyan, Parvez, Islam, Dampare, & Suzuki, 2010; Kebo & Bunch, 2013; POLIS with Columbia Basin Trust and Living Lakes Canada, 2018; Teck Resources Limited, 2014; Vandecasteele et al., 2015), but less is understood about how resource extraction continues to affect water quality long after it is stopped (Venkateswarlu et al., 2016). Resource extraction activities, such as mining generally involves massive displacement of earth and vegetation in the process of accessing mineral-rich ore bodies. The dissembling of natural geographic features can lead to irreversible landform changes, exacerbated erosion, acid rock drainage, contaminated soil, surface and ground water alterations, loss of species vegetation and habitat (Palmer et al., 2010). Further, health consequences can remain even after extraction activities have ceased, including those that result from water quality degradation and heightened exposure to metals and chemicals to aquatic and terrestrial wildlife, and humans even after remediation efforts (Palmer et al., 2010).

As one response, communities in the province of British Columbia have begun to create local watershed-based groups (Fraser Basin Council, 2016; Hunter et al., 2014; Okanagan Water Stewardship Council, 2008; POLIS with Columbia Basin Trust and Living Lakes Canada, 2018; Tsolum River Restoration Society, 2016). The groups often hope to find solutions to concerns that have arisen such as declining fish stocks, drinking water quality, or conflicts between multiple users (e.g. Fraser Basin Council 2014, and the Cowichan Watershed Board Hunter et al. 2014). The approach to creating watershed groups aligns with broader trends in governance in Canada, where statutory decision-makers and local citizens are beginning to recognize the need for more direct civic engagement at local watershed scales (Bakker, 2007b; Bakker & Cook, 2011; Brandes et al., 2007; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007). Watershed boards and roundtables are aiming to build collaboration and partnerships that can proactively consider resource-based decisions (Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007). This is an attempt to address governance issues from a bottom-up approach where communities have a more established and formal role in some of the decisions that are made within their watershed (Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Hunter et al., 2014). Citizens can voice local interests, and participate in decisions around ecological, economic and social values (Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Hunter et al., 2014). While many of these watershed-based groups recognize water quality as a priority on agendas for reaching healthy fish habitat, there has been limited research that explores the specific water quality parameters that are motivating the creation of these local watershed groups (Fraser Basin Council, 2014; Harvey & Greer, 2004; Nelitz, Murray, Porter, & Marmorek, 2006; Pacific Fisheries Resource Conservation Council, 2006). The reality is that there is often an absence of data and information about water quality in watersheds in the province, and across the country (Moore, Shaw, & Castleden, 2018).

Prior to the growing emergence of watershed groups, the Province of British Columbia conducted the Water Use Planning (WUP) program. The program was designed to revise the operating plans of BC Hydro's hydroelectric facilities in order to improve the protection of social and environmental values beyond hydro production, and was intended to resolve conflicts that had escalated in the early 1990s among dam operators, environmentalists, industry stakeholders, local communities, First Nations and government (Scodanibbio, 2011). The development of 23 WUPs spanned across the province within a six-year period, and the WUP process applied a structured participatory decision-making process to incorporate input from an inclusive range of actors, including First Nations, government agencies, and community stakeholders. The intention was to ensure any revised operational plan was based on both local knowledge and relevant scientific information specific to the watersheds (Scodanibbio, 2011) and that the plan considered "tradeoffs". That is, to establish dam flow rates that were economically feasible while considering ecological and social values expressed by the stakeholders in the watershed. However, once completed numerous other issues still remained that were beyond the scope of the WUP process, for example: water quality concerns from contamination by improper disposal or contamination from logging practices (Johns, Chan, Gunardi, & Felker, 2014), mining contaminants from previous mines that are no longer active (Capital Regional District, 2014), the extinction of Pacific salmon runs (BC Hydro, 2002, 2003; Capital Regional District, 2014; Hydro, 2016; Wright & Guimond, 2003), and the recognition of local First Nations' watershed values (BC Hydro, 2002).

Consequently, years after the WUP processes, local advocates in some watersheds that had undergone a WUP were still struggling to have their concerns heard by government decision-makers and industry. Therefore, in some watersheds, communities have begun to focus on the creation of a watershed-based group as an institutional mechanism for greater influence in water governance and water management in the watershed (Hydro, 2016). It could be hypothesized that a watershed with a completed WUP "should" have the capacity for effective watershed governance present. But such a hypothesis has not been explored, and therefore, it is uncertain whether a watershed with a WUP is "ready" for success in implementing the local watershed governance model. In order to assess the "readiness" of a watershed to implement a watershed governance model, a framework is needed to examine the governance capacity. A framework proposed by Gupta et al. (2010) examines not just the capacity to govern, but a method to assess adaptive capacities for institutions to be commensurate with the rate of environmental change, such as local watershed-based group.

Beyond the WUP process, the Province of British Columbia has also recognized the need for local communities to become more engaged in the decision-making process in the development of water policy, and has enabled the delegation of select governance responsibilities to local watershed institutions in the new *Water Sustainability Act (WSA)* (Brandes & O'Riordan, 2014; Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017). A distributed governance regime is perceived as needed to address resource management challenges at a local watershed scale to enact harmonization and liaison between all scalar jurisdictions of governance.

This change in legislation mirrors a trend in scholarship on watershed planning and governance, which has similarly been advocating for alternative models to empower local communities in watershed governance. Scholars have suggested that certain conditions are important in ensuring success for this form of local watershed governance, including: transparency and accountability mechanisms (C Hill, Furlong, Bakker, & Cohen, 2008), collaboration (Muldoon & McClenaghan, 2007), clear rules and enforcement (Cohen & Davidson, 2011), monitoring of the watershed and accessible information for all involved and affected (Brandes & O'Riordan, 2014), equal partnerships with Indigenous Nations (Walkem, 2007), harmonization with all scales of government (Reed & Bruyneel, 2010), clear articulation of ethics (fairness, values) (Matthews, Gibson, & Mitchell, 2007), available funding (Brandes & O'Riordan, 2014), and shared decision-making procedures (Brandes & O'Riordan, 2014; Reed & Bruyneel, 2010).

Questions remain about whether these conditions and capacities are present in watersheds though, even where previous participatory planning processes have occurred. Despite this, many watershed-based groups are emerging and pushing for greater governance authority. In this research, I have explored the research question: if and how has the WUP process contributed to creating watershed governance capacity?

To examine this question, I will focus on the case of the Jordan River watershed on Vancouver Island, British Columbia. A WUP was undertaken in this watershed in 2000, but numerous issues remained beyond the scope of the WUP, including the lack of information about critical issues in the watershed such as water quality concerns from an inactive mine. Therefore, in addressing the overall research question, I examined two sub-questions: i) how have resource operations affected freshwater quality implicated in the WUP, and ii) how does a watershed community address concerns in a watershed planning process, like the WUP, through developed adaptive capacity?

In addition to addressing these two sub-questions and the overall research question, the following research objectives were achieved:

1) Document the WUP process challenges and the relationship of those challenges to long-standing historical developments in the watershed that have affected water quality and quantity.

2) Assess the current environmental state of the water quality in the Jordan River watershed through quantitative field analysis of water quality sampling in accordance with Ministry of Environment guidelines to understand the primary water issues of concern in the watershed; in addition, contribute to data that is provincially applicable, repeatable and useful in future water-related decisions.

3) Test a framework for assessing the presence of an adaptive capacity within the emerging watershed-based group through qualitative analysis of interviews with industry stakeholders, Indigenous governments, settler government agencies, and community.

4) Examine the perceptions of those engaging in watershed initiatives to understand the current approaches to water issues in the basin, and the links of the existing capacities in the previous WUP process.

**Thesis Outline**

The thesis is composed of four chapters which are summarized here:

**Chapter 1** includes an introduction and examination of the water management and water governance literature. The literature reviews the current state of water governance in Canada, and what initiatives or new approaches to local watershed governance are emerging in British Columbia, including relevant supporting policies for local watershed-based groups. The literature regarding the WUP process implemented by BC Hydro, one of British Columbia’s largest hydropower producers, outlines successes and challenges to the engagement process of the WUP, including the lingering need for more local engagement processes beyond the scope of the WUP process. In order to assess whether the WUP processes in the Jordan River watershed did contribute to watershed governance “readiness”, a framework is needed to examine the governance capacity. This chapter introduces a framework proposed by Gupta et al. (2010) which examines not just the capacity to govern, but a method to assess adaptive capacities for institutions to be commensurate with the rate of environmental change, such as local watershed-based group. The six capacities by Gupta et al. (2010) were explored and applied as a framework to assess local water governance of an emerging local watershed-based group. Based on this review, the approach for addressing the research question is then introduced. I describe the mixed methods research methodology used which combines both quantitative and qualitative data collection and analysis and uses the case study of the Jordan River Basin. The chapter concludes with a discussion on researcher positionality, including precautionary approaches taken to control potential bias and subjectivity in this research.

**Chapter 2** presents case study findings from the Jordan River in British Columbia, Canada – a watershed that was heavily influenced by resource extraction activities including mining, forestry and hydropower. This study focused on quantitative data by examining the water quality of the Jordan River, where an inactive underground copper mine lies below the Jordan River, and high copper concentrations leaching from the mine are suggested to be responsible for the loss of the historic Pacific salmon runs in the Jordan River. Water quality samples were collected over a five-week period from five sites on the Jordan River during a Fall freshet initiated by rainfall in September and October of 2015. In addition to water quality samples, select material were reviewed to understand current and historic watershed user groups, including government, First Nations, and resource industry roles; in addition to community perceptions and water quality concerns. Spatial and seasonal trends were identified, and the analysis demonstrated that copper is the primary contaminate affecting salmon habitat health in the

Jordan River. Acid mine drainage processes were identified throughout the water quality data and are strongly influenced by the proximity of existing mine waste piles sourced from an abandoned copper mine, unnatural anthropogenic flows from the three BC Hydro dams present in the river system, and the wet coastal climate in the Jordan River watershed. The three reservoirs on the Jordan River system further complicate the cycling and transport of dissolved organic carbon (DOC), which plays an essential role in balancing aquatic chemistry as it can combine with other metals and nutrients, and buffer toxicity to aquatic life. The water quality concerns were a major issue that was brought up continually during the consultative process of the WUP but were concluded to be beyond the scope and responsibility of the WUP. Local advocates shifted from a water management process, such as the WUP, to local water governance initiatives fifteen years after the WUP consultative process and began to assemble a watershed-based group to address these concerns.

**Chapter 3**. The Gupta et al. (2010) six adaptive capacity dimensions provide a logical framework to explore if these developed adaptive capacities are present in the local watershed organization such that one could expect local watershed organizations to be effective as society adapts to a more watershed-based governance approach. Thirteen semi-structured interviews were conducted from October 2016 to February 2017. Interviews focused on the WUP and prospective and current members of the Jordan Watershed Round Table (JWRT). The analysis examined their perspectives on meeting the six adaptive capacity dimensions using the Gupta et al. (2010) framework. This research evaluated whether these six adaptive capacity dimensions are present in watersheds that have been subjected to water management processes, specifically WUP program.

**Chapter 4** provides a conclusion and summary of the main themes, findings, limitations and contributions documented in the thesis.

## Literature Review and Framework

The literature reviews the current state of water governance in Canada, and what initiatives or new approaches to local watershed governance is emerging in British Columbia, including the WUP process and relevant supporting policy for local watershed-based groups. A framework proposed by Gupta et al. (2010) describes successful adaptive capacities of local watershed governance.

### Canada's Traditional Approach to Water Governance

Freshwater withdrawals and in stream water resources contribute $7.5 billion to $23 billion to Canada's economy annually (Shrubsole & Draper, 2007). Canada is one of the world's largest diverters of water for hydropower (Bakker, 2007b). The development of hydraulic infrastructure, such as hydropower dams, tends to be favored globally by decision-makers whether these motivations are fueled by political gain, budget expenditures or business opportunities (Molle, 2009). This type of water resource development has contributed immensely to the overbuilding of river basins (Molle, 2009). Basin overbuilding motivates powerful decision makers through opportunities of economic incentives (Molle, 2009). Politicians cherish iconic large-scale infrastructure as symbolic representations of their success, and to build their constituencies (Molle, 2009). Government technical agencies, bureaucracies, and private consulting firms need professional projects to ensure future budgets (Molle, 2009). Development banks and corporation agencies view large-scale projects as opportunities to disburse funds (Molle, 2009). Basin overbuilding leads to water resources being invariably exploited to a point where systems can no longer fulfill their natural functions (Bakker & Cook, 2011; Booth & Skelton, 2011; Brandes & O'Riordan, 2014; Molle, 2009; Place & Hanlon, 2011). Fragile fish habitats struggle to maintain necessary temperature, flow, and quality requirements in highly developed basins (Wright & Guimond, 2003). Ecological functions in riparian areas decrease with watershed health (Brandes & O'Riordan, 2014). Increased water use and contamination associated with development of resource extraction activities jeopardize valuable fresh water sources (Brandes & O'Riordan, 2014; Renzetti &

Dupont, 2017). Watersheds are unable to cope with the pressures generated by development, which deplete available water leading to a decrease in the overall resiliency of the system (Molle, 2009).

Canada's paradigm of supply-management still dominates attitudes in water policy (Bakker, 2007b; Brandes et al., 2007; Muldoon & McClenaghan, 2007; Renzetti & Dupont, 2017). A characteristic of supply-management focuses on engineering large centralized infrastructure to control natural processes to meet human needs (Brandes et al., 2007; Mitchell, 2017). It is based on the belief that technology and financial costs are the only limiting factor to curbing natural systems to provide eternal services (Brandes et al., 2007). Growth is modeled by past extrapolations that reflect an increase in a higher capacity to meet future needs (Brandes et al., 2007). This type of management supports large engineered projects, and depicts an assumption that water is not a valuable resource (Brandes et al., 2007). Although supply-management has been successful in providing a basis for Canada's economy, it encompasses little incentives for efficiency and conservation (Brandes et al., 2007; Sprague, 2007).

Historically, water policies have supported the supply-management focus by satisfying the demands of the human population through supplying water, power generation, resource development, agriculture, and recreation (Brandes & O'Riordan, 2014; Mitchell, 2017). Ecological values were not considered in the creation of water policies and have resulted in irreversible damage to natural freshwater habitats (Brandes & O'Riordan, 2014). The lack of a federal water strategy that could encompass some of these ecological values is argued to be due to the fact that water issues are too complex and have a direct impact on the economy and stakeholders (Muldoon & McClenaghan, 2007). Scholars have recognized that water licensing in Canada has always focused on supporting industrial activity and has lacked commitments to ecological and social values (Christensen & Lintner, 2007; Curran & Mascher, 2016). Moreover, these environmental and social concerns have not always been considered in water policy, since in recent history, there were limited opportunities for the public to engage in water-related decisions (Muldoon & McClenaghan, 2007). Although this is becoming more widely recognized, there is an ongoing disconnect between decision makers and local actors in a watershed, who are affected by these decisions.

**Gaps and Challenges**

The major challenge of managing freshwater resources in Canada stems from the inability of governance to address conflicting views on how water should be managed in a robust governance framework (Bakker & Cook, 2011; Muldoon & McClenaghan, 2007). The management of freshwater resources are scattered separately amongst four orders of governance: municipal, provincial, federal and First Nations. The distribution of freshwater responsibilities has resulted in fragmentation between jurisdictions and scales of governance (Bakker & Cook, 2011; Brandes & O'Riordan, 2014; Muldoon & McClenaghan, 2007; Renzetti & Dupont, 2017). Overall, water resources are primarily governed by the provinces and territories, where direct constitutional powers focus on water use, land management and control of local governments (Brandes & O'Riordan, 2014). The constitutional divisions of powers of water governance are divided amongst multiple ministries and departments with complex mandates (Bakker & Cook, 2011). The provincial and territorial governments further decentralize water responsibilities to municipal governments and private actors (Bakker & Cook, 2011). The role of the federal government in water governance is unclear and has been argued to be in a state of retreat (Bakker, 2007b; De Loe & Kreutziser, 2007). The responsibilities of the federal government are mainly navigation, fisheries, trans boundary waters and First Nations affairs (Bakker & Cook, 2011; Brandes & O'Riordan, 2014; Muldoon & McClenaghan, 2007; Shrubsole & Draper, 2007). There is no clear authority for environmental matters, which is shared between federal and provincial governments (Bakker & Cook, 2011).

The flaws of inter-governmental coordination have led to inadequate data collection and accessibility, minimal efforts in monitoring and enforcement, and repeated efforts that are often inefficient (Bakker & Cook, 2011). The fragmentation has created significant governance gaps, challenges, and overlaps in Canadian water policy (Bakker & Cook, 2011; Brandes & O'Riordan, 2014).

**New Approaches in Canadian Water Policy**

The landscape of Canadian water policy has changed significantly in recent years from a resource-extraction based top-down approach to "moments" or "pieces" of including greater transparency in governance, increasing public participation, and new policy initiatives by provinces (Renzetti & Dupont, 2017). These changes have been evident in British Columbia, where new legislation has integrated ecological values into water policy, including the establishment of water objectives and protection of critical environmental flows in regulation (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017). The law has potential to improve planning and governance at a localized level outlining provisions for shared and delegated decision-making (Brandes & Simms, 2018; Curran & Brandes, 2017). Overall, water managers have been recognizing a need for a more collaborative approach where all governments, rights holders and stakeholders have a role in decision making (Curran & Brandes, 2017).

***Watershed Planning in British Columbia***

In British Columbia, a number of watershed planning programs are being implemented to include public participation amongst communities, industry stakeholders and Indigenous nations in water related decisions (Fraser Basin Council, 2011). BC Hydro's WUP is as defined as a multi-stakeholder approach to managing economic, social, cultural, environmental and ecological values of freshwater associated with BC Hydro's hydroelectric facilities (Gregory, Failing, & Higgins, 2006; Scodanibbio, 2011). The WUP planning process develops a series of guidelines that revises the operating procedures of 30 hydroelectric facilities based on the inclusive input of a variety of site-specific values defined by local actors and relevant scientific information (BC Hydro, 2003; Gregory et al., 2006; McDaniels, Gregory, & Fields, 1999; Scodanibbio, 2011). The program incorporates concepts of adaptive management in social-ecological systems, where adaptive management provides flexible and responsive management approaches over time and incorporates value-focused ethical thinking, collaboration, and structured decision making (Scodanibbio, 2011). The aim of the WUP process is to meet the ongoing economic goals of the hydroelectric facilities, but also to better incorporate social and environmental values expressed by stakeholders which were neglected back when many of the facilities were first constructed (Scodanibbio, 2011). The WUPs are claimed to have resulted in improvements to fisheries, and revolutionized cooperative partnerships amongst stakeholders with reestablished trust in industry (Scodanibbio, 2011).

The WUP process has presented challenges in managing economic trade-offs for power production that improves ecological fish habitat downstream, such as implementing base flow targets that meet economic and operational targets, but lack the support of scientific baseline data to evaluate whether these base flows will have a positive or negative effect on fish habitat downstream (Gregory et al., 2006). In addition to these challenges, the WUP program is a participatory and engaging process but it lacks addressing watershed concerns outside of the scope of the licence for power production. For example, the WUP is not responsible for managing water quality issues created by mining companies or sedimentation due to logging operations in watersheds. Watershed planning programs like the WUP are well-funded and structured, but do not present a holistic approach to over-arching watershed concerns or harmonizing the fragmentation between jurisdictions and scales of water governance.

***Watershed Governance***

The scale at which watershed issues need to be addressed are at a finer resolution than what the current government framework offers. Semi-formal local entities are viewed as a solution to address specific concerns that are unique to watersheds (Brandes & O'Riordan, 2014). Citizens are beginning to articulate the need to create a new 'layer' of governance at local watershed level (Bakker, 2007b; Bakker & Cook, 2011; Brandes et al., 2007; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007). Recently there has been a global shift in policy within environmental governance, as nations are beginning to realize that governance functions need to be extended upwards to international institutions, downwards from national to local actors, and outwards to include non-state actors (Reed & Bruyneel, 2010). This form of governance involves formal and informal institutions, social groups, citizens, natural processes, ecological interactions and traditions into the decision-making process (Reed & Bruyneel, 2010). As a result, local organizations and non-profit actors are collaborating to fill in the voids where governance is failing or lacking. Communities have begun to establish a variety of watershed-based organizations to tackle specific watershed issues and collaborate with municipal, provincial, and federal levels of government (Brandes & O'Riordan, 2014; C Hill et al., 2008; Nowlan, 2010). In general, it appears that watershed boards and roundtables are becoming a desired way to organize people within a watershed for collaboration and partnerships in water resource decisions (Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007), and this trend appears to be growing stronger in British Columbia in recent years (Morris & Brandes, 2013).

However, questions remain about the capacity of these watershed groups to enable a new form of water governance at a local watershed level. Water governance capacity is defined as the level of competence to implement effective water arrangements through policy, laws, institutions, regulations and compliance mechanisms (International Union for Conservation of Nature, 2009). Scholars argue that water governance capacities should be assessed as an ongoing process to implement reform and adapt to variability and change (Gupta et al., 2010; International Union for Conservation of Nature, 2009).

***New Legislation: B.C.'s Water Sustainability Act***

British Columbia's 2016 *WSA* modernizes the 106-year-old *Water Act*, and was created on the participatory basis of recommendations from a number of diverse water user groups (Brandes & O'Riordan, 2014). First Nations, industry, academia, professional experts, local governments and non-governmental organizations have contributed to the new legislation in the *WSA* (Brandes & O'Riordan, 2014). The *WSA* attempts to address prominent water challenges and promote sustainability. Features of the *WSA* include the ability to improve management of water as a single resource, protect environmental flows, enhance water quality, and integrate land and water decision-making by enabling innovative approaches to planning and governance (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017).

The *WSA* promotes a bottom-up approach to watershed management and aims to coordinate governance approaches throughout a provincial to local level (Brandes & O'Riordan, 2014; Brandes & Simms, 2018; Hunter et al., 2014). The *WSA* has offered an opportunity to delegate select governance responsibilities to local watershed institutions by providing formalized mechanisms to inform policy and improve statutory decisions through advisory boards (Brandes & O'Riordan, 2014; Brandes & Simms, 2018). The *WSA* also creates possibilities for the delegation of Provincial authority when applied to specific aspects of the *WSA* decision-making process, including comprehensive Water Sustainability Plans (Brandes & Simms, 2018).

These new provisions under the *WSA* modify the ongoing "priority system" in the former *Water Act,* where extractive purposes were granted to users based on "first in time, first in right" (FITFIR) water licence allocation (Brandes & Simms, 2018; Curran & Brandes, 2017; Curran & Mascher, 2016). The former *Water Act* neglected to provide the ability to address any ecological or social issues caused by the rigid priority system (Brandes & O'Riordan, 2014; Curran, 2017). The new regulatory approaches in the *WSA* focuses on protecting stream health, ground water regulation, water allocation, watershed sustainability planning, monitoring and reporting of major water use, and collaborative governance (Brandes & O'Riordan, 2014; Brandes & Simms, 2018). The *WSA* exhibits a strong feature to adaptively manage water alongside ecological conditions, by considering environmental flow standards and adapt regulation to deteriorating conditions (Curran, 2017). Social and ecological interests are incorporated in the regulation of the *WSA* to provide a baseline for sustainable and long-term management of water resources (Brandes & O'Riordan, 2014).

The *WSA* presents a unique and promising opportunity for local watershed governance in British Columbia, but it is still too early to know how the *WSA* will be implemented. Unfortunately, most of the work in developing standards, data and development of water sustainability plans remain (Brandes & Simms, 2018; Curran, 2017). Another major flaw of the *WSA* is the lack of commitment to acknowledging First Nation rights holders' interest in water (Curran, 2017, 2019; Gullason, 2018; Joe, Bakker, & Harris, 2017). The watershed governance criteria to implement the Advisory Boards (s. 115) and Delegated Authority (s. 126) under the *WSA* that could help enable watershed-based institutions has not yet been specified (Brandes & Simms, 2018; Water Sustainability Act, 2014). Furthermore, even if the Province wants to move forward with these delegations and advisory boards under the *WSA* it is unclear which watershed-based institutions have the capacity to take on these new provisions.

**The Adaptive Capacity Framework**

As stated, recent scholarship has highlighted key conditions and capacities that are important to the success of local watershed governance. Therefore, as an increasing number of watershed groups emerge and in light of the opportunities within BC presented by the legislative changes at the provincial level, there is a need to better understand whether capacity exists to implement a different model for governance. Across the scholarship, one major theme is that local watershed governance will need to be adaptive (Curran & Mascher, 2016; Foerster, 2011; Gregory et al., 2006; Joe et al., 2017). Scholars have argued for the importance of developing adaptive institutions or governance regimes that respond positively to change through mechanisms for close monitoring, learning and improvement (Curran & Mascher, 2016; Foerster, 2011; Gregory et al., 2006; Joe et al., 2017). Watershed-based institutions should be adaptive to the needs, values and interests of watershed actors overtime. Adaptive management strategies involve dealing with uncertainty and changes in economic, social and environmental conditions (Gregory et al., 2006). Watershed-based institutions need to be adaptive in the context of changing environmental conditions given climate change (Garrick, 2017). Therefore, one framework that could be useful for assessing watershed governance capacities is known as the Adaptive Capacity framework developed by Gupta et al. (2010).

Gupta et al. (2010) indicate that certain adaptive capacities need to be present for society to respond to climate change and whether institutions need to be redesigned to meet these specific capacities. Gupta et al. (2010) define adaptive capacity as “the inherent institutions that empower social actors to respond to short term and long term impacts either through planned measures or allowing and encouraging creative responses from society both ex ante and ex post”. The adaptive capacity dimensions are developed to understand how society can transition into effective decisions that adapt to a changing climate. Further, Gupta et al. (2010) argue that these adaptive capacity dimensions can be applied to different institutions beyond climate change, and provide a methodology to assess whether institutions need to be redesigned by using their ‘Adaptive Capacity Wheel”. The six adaptive capacities outline a framework developed by Gupta et al. (2010), where the criteria were derived from literature that focuses on assessing institutional adaptive capacity of organizations. One could argue that these adaptive capacities would be equally applicable to watershed-based group. The following sections describe the six adaptive capacities and the ‘Adaptive Capacity Wheel’ of the Gupta et al. (2010) Adaptive Capacity framework.

**Variety**

Variety implies that no single appropriate ideological framework exists, optimal policy strategy or set of mutually consistent solutions, and decisions are reached by a variety of actors that offer diverse perspectives to address a number of different problem frames and solutions (Gupta et al., 2010). Variety promotes diversity and requires an institution to have a range of proactive strategies that understand complication (Gupta et al., 2010). In terms of watershed governance, an organization should incorporate concepts of variety, such as being comprised of representatives from diverse user groups with varying interests and perspectives which can lead to collaborative and shared decision-making processes with a number of proactive strategies that face complexity (Brandes & O'Riordan, 2014; Reed & Bruyneel, 2010; Walkem, 2007).

**Learning Capacity**

Gupta et al. (2010) describe the learning capacity of the institution as enabling social actors to learn and improve their institutions by building trust amongst one another (Brandes & O'Riordan, 2014), learning from past experiences of other institutions or watershed groups, providing opportunity for actors to challenge the norms and address uncertainties, and stimulate institutional memory by monitoring and evaluating the processes of policy experiences. Such a capacity requires: establishing trust amongst one another, having mechanisms or processes for 'single loop learning' which allows institutions to learn from past experiences, and 'double loop learning' by providing opportunities for actors to challenge the norms, address uncertainties, and a means for stimulating institutional memory by monitoring and evaluating the processes of policy experiences (Gupta et al., 2010).

Learning capacity can include incorporating a clear articulation of ethics through fair practices in shared-decision making that acknowledge water-user values to build trust amongst participants of a local watershed-based group (Matthews et al., 2007) and foster adaptive approaches to policy implementation for future improvement that adapts to a dynamic governance system (Hurlbert & Gupta, 2016).

**Room for Autonomous Change**

The adaptive capacity "room for autonomous change" calls for institutions to enable social actors to anticipate possible futures, and plan preventative measures against threats through continuous access to information, action plans and capacity to self-organize or improvise with resources at hand (Gupta et al., 2010). This can include the gathering and access to scientific information within the watershed through continuous monitoring and evaluation that can be used to inform decision-makers and highlight potential challenges in the watershed that can influence preventative planning measures

(Armitage et al., 2015; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Robinson, Bark, Garrick, & Pollino, 2015).

**Leadership**

Leadership capacity is described as the establishment of long term-visions and goals of the institution, such as the long-term goals of a watershed-based group (Brandes & O'Riordan, 2014; Mitchell, 2009), and enabling collaboration that encourages shared-decision making amongst different watershed actors (Cohen & Davidson, 2011; De Loe & Kreutziser, 2007; Gupta et al., 2010; Muldoon & McClenaghan, 2007; Reed & Bruyneel, 2010). Gupta et al. (2010) outline three criteria for leadership capacity including visionary leadership working towards long-term goals, entrepreneurial leadership through leading by example, and collaborative leadership by enabling a variety of actors.

**Resources**

The access to both human and financial resources is an essential capacity for effective watershed governance, where there is access to knowledge, skills, expertise and labor through human resources and is supported by on-going available funding from financial resources (Bakker, 2007a; Brandes & O'Riordan, 2014; Gupta et al., 2010). A watershed group with valuable resources both human and financial would have sustainable and ongoing funding, and access to scientist, consultants, experts such as in academia and volunteers to carry-out and inform watershed-based projects such as river restoration. Gupta et al. (2010) outline three criteria for assessing resources capacity including the provisions of authority through accepted or legitimate forms of power (either legal or political mandate), availability of skills and labor through human resources and the capability for the institution to be supported by on-going funding from financial resources.

**Fair Governance**

Fair governance includes establishing legitimacy through public support and acceptance by gaining the trust of the public, equity which should be reflected in fair institutional rules, transparency needs to be evident in institutional processes, responsiveness of the institution to different voices of society, and accountability in institutional procedures (Gupta et al., 2010). Water governance literature supports incorporating a clear articulation of ethics through fair practices in shared-decision making that acknowledge stakeholder values to build trust amongst participants (Matthews et al., 2007), transparency (Brandes & O'Riordan, 2014; Cohen & Davidson, 2011; Carey Hill, Furlong, Bakker, & Cohen, 2008), harmonization amongst various scales of governance (Bakker, 2007a; Brandes et al., 2007; Nowlan, 2007; Reed & Bruyneel, 2010; Taylor, Loë, Bjornlund, de Loë, & Bjornlund, 2013) and enforcing accountability amongst users in watershed-based governance (Cohen & Davidson, 2011; Carey Hill et al., 2008).

**The Adaptive Capacity Wheel**

The adaptive capacity wheel was a tool designed to assess the adaptive capacities of institutions, where the inner circles displays the adaptive capacity dimensions and the outer circle encompasses the corresponding criteria (Gupta et al., 2010) (Figure 1). A color scoring scheme is applied to the wheel to distinguish between high (green: quantitative value +2) to low (red: quantitative value -2) adaptive capacity to assess how institutions influence different aspects of adaptive capacity and outline areas of discussion and reform.

**Figure 1**

*The Adaptive Capacity Wheel*


| Effect of institution on adaptive capacity | Score | Aggregated scores for dimensions and adaptive capacity as a whole |
|---|---|---|
| | | |
| Positive effect | 2 | 1.01 to 2.00 |
| Slightly positive effect | 1 | 0.01 to 1.00 |
| Neutral or no effect | 0 | 0 |
| Slightly negative effect | -1 | -0.01 to −1.00 |
| Negative effect | -2 | -1.01 to −2.00 |

*Note.* Reprinted from "The Adaptive Capacity Wheel: A method to assess inherent characteristics of institutions to enable the adaptive capacity of society," by J. Gupta, C. Termeer, J. Klostermann, S. Meijerink, M. van der Brink, P. Jong, S. Nooteboom, and E. Bergsma, 2010, *Environmental Science and Policy, 13*(6), p. 459–471. (https://doi.org/10.1016/j.envsci.2010.05.006). Copyright 2010 by Elsevier Ltd.

## Case Study Methodology

Case studies are one broadly accepted approach to research in the social sciences, and is an appropriate methodology in expanding and developing new explanatory concepts (Baxter, 2010; Blatter, 2008). A case study is well suited to expand on "how" questions (Yin, 2009), such as how have resource extraction practices affected water quality, and how are water use planning processes influencing watershed governance capacity in British Columbia. This case study expands on the concept of how has the WUP process contributed to creating watershed governance capacity? A case study is well defined by Gerring (2004, 342) as 'an intensive study of a single unit for the purpose of understanding a larger class of (similar) units' (Baxter, 2010), such as the focus of this research on a single watershed that is in the initial stages of forming a local watershed-based group in response to resource operations, where lessons could be learned and applied to other watersheds impacted by resource operations that are seeking similar goals in local watershed governance across British Columbia.

Although, case study research has been criticized as being difficult because of the challenges with generalizing findings of a singular case beyond the case study or region, it is argued that case study research is an ideal choice when the objective is not to make broad generalizations, but focusing on achieving in depth information about a given problem of phenomenon (Flyvbjerg, 2006). Case study methodology has an advantage in terms of internal validity, where a single case study can provide concrete conclusions in comparison to large-scale surveys that reflect average conclusions generated across a broader sample. The Jordan River is a unique and dynamic case and the results of this research provides concrete conclusions to the social challenges with resource operations that are being addressed by the local watershed governance initiatives across British Columbia (Brandes et al., 2007; Brandes & O'Riordan, 2014; Hunter et al., 2014; Parfitt, Batutis, & Brandes, 2012).

**Case Study Context**

A number of criteria were used in selecting a case study that provided further insight to watershed governance in British Columbia. The criteria were chosen to meet the scope of an exploratory mixed methods research approach that included both quantitative and qualitative data collection reflective of a social science graduate project. The results of the research needed to be applicable elsewhere in British Columbia; therefore, the case study needed to consist of diverse watershed user groups that were representative of other watersheds in British Columbia. A number of cases on Vancouver Island (Hunter et al., 2014) and lower mainland (Barry et al., 2000) were considered, where resource operations had led to the creation of local watershed groups, some that were already in their advanced stages. The researcher was familiar with some of the issues that had evolved in the Jordan River watershed, and chose her case to be on a watershed that provided an unique opportunity for exploratory research where resource operations had not been examined over a spatial and seasonal water quality scope, watershed planning had been implemented, and the watershed was in the initial stages of enabling local watershed governance. The Jordan River watershed was a suitable case that met each of these. Selection criteria are summarized in Table 1.

**Table 1**

*Case Study Selection Criteria*

| | Case study selection criteria | How does the Jordan River watershed meet the selection criteria? |
|---|---|---|
| **1** | The implementation of watershed planning within the watershed. | The presence of active hydropower dams that underwent the BC Hydro WUP review process in Jordan River, including three active hydropower dams, two reservoirs and a powerhouse located along the river (BC Hydro, 2003). These generating facilities are part of BC Hydro's integrated generation system and contribute to the only major hydroelectric development on the southwest coast of Vancouver Island (BC Hydro, 2003). |
| **2** | The current state of the watershed had not yet been explored within a spatial and seasonal water quality scope. | Existing water quality and ecosystem health issues that were addressed In the WUP engagement process, but are beyond the scope of the Jordan River WUP including metal toxicity from historic mining operations (BC Hydro, 2003). The Jordan River watershed once hosted native salmon runs of coho, pink, and chum that no longer exist due to the cumulative effects of multiple resource extraction activities that are present within the watershed (Wright & Guimond, 2003). Over the last few decades, |

| | | |
|---|---|---|
| | | research suggests that copper contaminants from an abandoned underground copper mine have been continuously leaching into the river and have contributed to the loss of aquatic life in the lower reaches of the Jordan River (Wright & Guimond, 2003). Yet, there had not been an extensive water quality study conducted that examines the spatial and seasonal water quality extents of the mining contamination, specifically copper. |
| **3** | Watershed user groups are engaged in dialogue or development of local water governance initiatives. | An emerging dialogue and informal organization for local interests to engage in water decision-making in the watershed. There has been recent discussion about creating a local watershed-based group, the 'Jordan Watershed Round Table,' that involves community members, industry stakeholders, government agencies and First Nations to collaborate as a mechanism for greater influence in water planning and governance processes in the Jordan River watershed (Hydro, 2016), similar to neighboring watersheds on Vancouver Island, like the Cowichan Watershed Board, and Shawnigan Watershed Roundtable (Hunter et al., 2014). |
| **4** | The watershed user groups are representative of other watersheds in British Columbia. | The diversity of stakeholders within the watershed, including multiple resource industries (mining, forestry, and hydropower) both inactive and actively operable, First Nations, and rural community location; which similarly describes watersheds dominated by resource development in British Columbia. |
| **5** | The thesis research is applicable to other local watershed groups seeking similar goals in watershed governance in British Columbia. | The Jordan River is a dynamic case, where ongoing scientific information is constantly emerging and openly sourced, from the Jordan River WUP process review, provincial environmental assessment process, media, and meetings of the newly formed watershed-based group.<br>The research is valuable to the stakeholder groups and First Nations of the Jordan Watershed Round Table and may contribute to watershed decisions in the future. |

## Case Study Description

This section provides a thorough description of the physical geography, key resource development, watershed issues of concern, watershed planning processes and water governance initiatives currently at play in the Jordan River region.

### Geography of the Jordan River Watershed

The Jordan River watershed is located on the southwest coast of Vancouver Island approximately 72 kilometers from the provincial capital city of Victoria and governed by the Capital Regional District (Figure 2). The total area of the watershed is 165 square kilometers, and its hydrology is influenced mainly through precipitation and limited snowmelt that drains into the Juan de Fuca Strait (BC Hydro, 2003).

**Figure 2**

*The Jordan River Watershed*


*Note.* Reprinted from “Meeting Little Comfort for Jordan River Dam’s Path” by A. Smart, 2014, *Times*

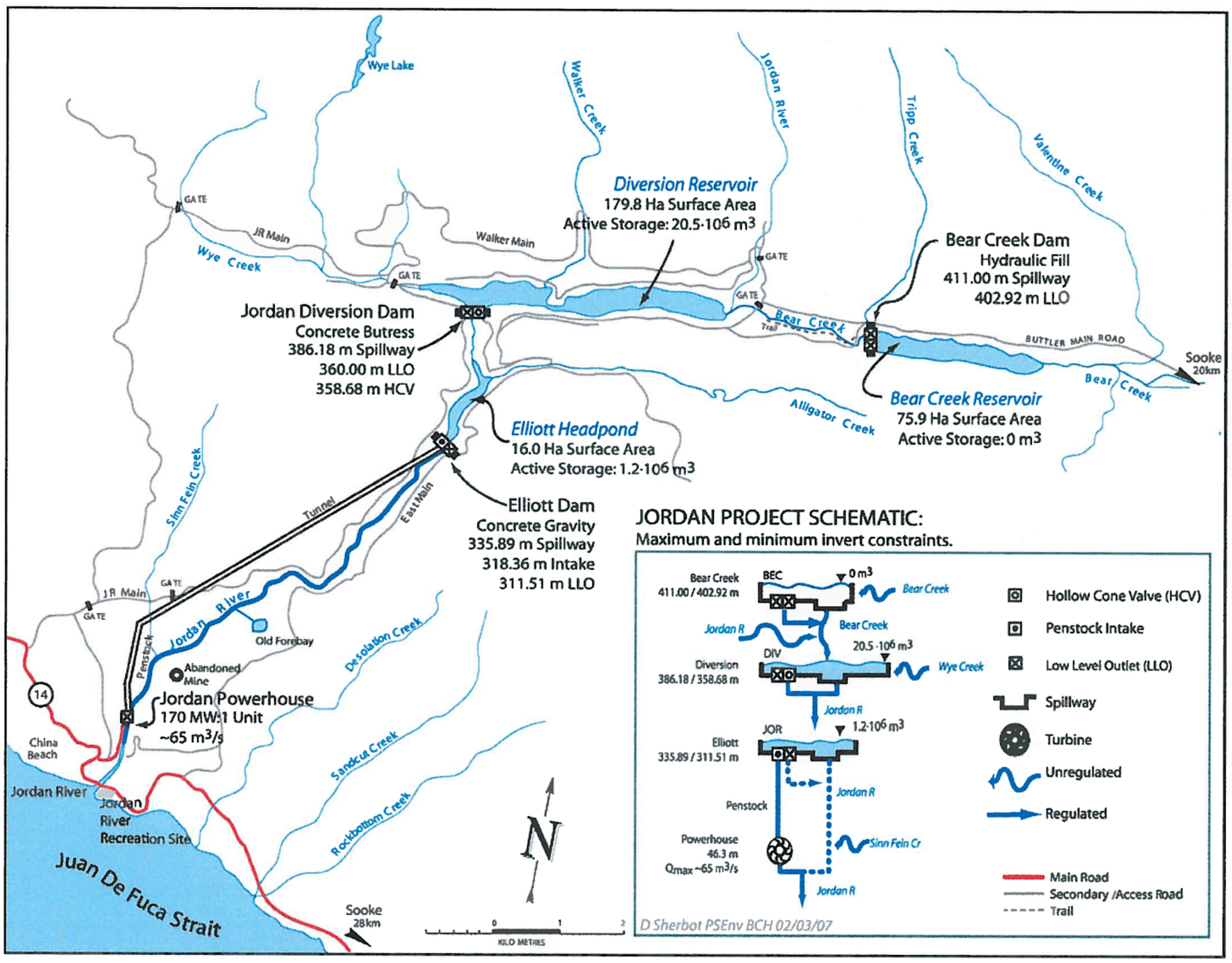
*Colonist*. (https://www.timescolonist.com/news/local/meeting-little-comfort-for-jordan-river-residents-in-dam-s-path-1.1664167).

The Jordan River estuary was historically the traditional hunting and fishing territory of the Pacheedaht First Nation. Pacheedaht settlements populated the mouth of the Jordan River, and were used seasonally to gather food for their community in Port Renfrew, B.C., approximately 40 kilometers north of the Jordan River. Resource extraction development began in the Jordan River watershed in the early 1900s, and resulted in the displacement of the Pacheedaht First Nation from their traditional hunting and fishing territory. Since then, the Pacheedaht have no longer been able to hunt, fish or harvest in the watershed due to the effects of resource development, which led to the permanent decline of salmon and wildlife populations in the watershed. Today, a rural community of 150 non-Indigenous people lives within the watershed. Jordan River is located within a stretch of coastline where provincial parks, coastal hiking trails, and campgrounds that attract high amounts of seasonal tourism exist. Year-round recreational users frequent the shores of Jordan River to pursue surfing and water sport opportunities. Historically, the Jordan River community was heavily dependent on an economy sustained by resource extraction operations within the watershed. Forestry, mining and hydroelectric operations are still currently active within the watershed today, including a dryland sort and booming operation that occupies the mouth of the Jordan River.

Hydroelectric development along Jordan River was initiated in 1909 and operated continuously from 1911 to 1971 (Wright & Guimond, 2003). In 1971, a 175 MW powerhouse was built to replace the original 26 MW powerhouse located on the east side of the Jordan River, which is still in operation today (Burt, 2012). The current powerhouse is part of a delivery system that has three hydropower dams, two reservoirs, a head pond, and a tunnel penstock delivery system in the Jordan River watershed (BC Hydro, 2003). The dams include Bear Creek Dam, which impounds Bear Creek Reservoir; Diversion Dam, which impounds Diversion Reservoir; and Elliot Dam, which impounds the Elliot Head pond (Figure 3). These generating facilities are part of BC Hydro's integrated generation system, and contribute to the only major hydroelectric development on the southwest coast of Vancouver Island (BC Hydro, 2003).

**Figure 3**

*BC Hydro Facilities in the Jordan River Watershed*




*Note.* Reprinted from *Jordan River Water Use Plan*, by BC Hydro, 2003.

The hydroelectric development in Jordan River can generate up to 175 MW of power, and could potentially sustain approximately 35% of Vancouver Island's total electricity demands (BC Hydro, 2003). However, approximately 80% of the power demands of Vancouver Island are supplied by a submarine cable transmission system from the Lower Mainland (BC Hydro, 2003) and therefore, the current operating role of the Jordan River facility is defined as a “peaking plant” to meet voltage demands during peak times of the day, and offsetting the effects of transmission failures that may occur on the provincial transmission grid system (BC Hydro, 2003). Power generation generally occurs in the early mornings and afternoons to suit the peak demands of the population living on Vancouver Island, which unnaturally alters the flow in the Jordan River daily.

**Mining Development in the Jordan River**

Copper mining began in the early 1900s and operated intermittently until 1977 when the main access tunnel of the mine collapsed. The mine was officially closed in 1993 by the Province of British Columbia. The inactive underground copper mine lies below the Jordan River, and is accessed approximately 1.5 kilometers upstream from the coast on the east side bank. The workings of the mine are evident along the riverbanks, where the Jordan River flows directly through a portion of the mine including the underground mill room. Large piles of waste rock, low-grade ore, tailings and mining debris have been deposited along the River’s edge and are estimated to be between 20, 000 and 30, 000 cubic meters (SNC Lavalin, 2016). A 15-centimeter wide submarine tailings pipe was constructed in 1961, and still exists today along the eastward lands of the River. The submarine tailings pipe extends one kilometer offshore, and is discharged at a shallow depth of 12 meters (Ellis, 2008). A total of 1.3 million metric tonnes of waste rock and tailings were generated from the production of the mine and 95% was deposited into the ocean at the mouth of Jordan River via the submarine tailings pipe (Burke, 2012). The other 5% of tailings and waste rock were deposited along the banks of the Jordan River. High copper concentrations sourced from the mine are suggested to be responsible for the loss of the historic salmon runs in the Jordan River (BC Hydro, 2003; Wright & Guimond, 2003). The copper mine was purchased in 2013 and are currently in the preliminary exploration stages of resuming operations of surface copper ore bodies with intentions to avoid the underground workings. In 2014, following the new purchase of the mine, the Ministry of Environment's Contaminated Sites department ordered the current landowners and previous mine owners, Teck Resources, formerly Sunro Mines Limited, to submit a site risk classification report pursuant to Protocol 12 of the *Contaminated Site Regulation.* The provincial investigation and plans for remediation are currently underway.

**Watershed Governance and Management in the Jordan River Watershed**

Watershed planning and governance in the Jordan River involved a variety of stakeholders and decision-making processes. The following descriptions outline the main processes that served as important context when this research was conducted. Table 2 summarizes a chronological timeline of key watershed events and initiatives in the Jordan River.

**Table 2**

*Chronology of Events and Initiatives in the Jordan River Watershed*

| Year | Event/Initiative |
|---|---|
| **1880s** | Forestry operations began. |
| **1900s** | Pacheedaht First Nations were displaced from their traditional fishing and hunting grounds in the watershed due to resource developments. |
| **1911** | BC Hydro hydroelectric project was completed. |
| **1919** | Mining operations began initially by Cominco (currently Teck Resources), which later formed into Sunro Mines Limited. The mine was operated intermittently at full capacity following the fluctuations in the price of copper. |
| **1934** | Forestry operations in the watershed were managed by Western Forest Products and log booming began in the lower portion of the Jordan River. |
| **1956** | The main access tunnel excavation was completed and extends 2.6 km along the Jordan River allowing access to a number of copper ore bodies resulting in an extensive network of underground tunnels. |
| **1958** | Chum salmon were no longer observed spawning in the Jordan River. |
| **1961** | Improvements to the mine were made including the installation of a submarine tailings pipe that discharged into the ocean east of Jordan River. |
| **1964** | The roof of the mine collapsed below the Jordan River, ultimately flooding the mine |

| | |
|---|---|
| | and dispersing debris, machinery, concentrate and sediment into the Jordan River. Dredging occurred in the river and materials were used to build a dryland sort on land reclaimed from the Jordan River estuary.<br>Log booming operations were halted and were trucked to Sooke. |
| **1966** | Coho salmon were no longer observed spawning in the Jordan River. |
| **1967** | Log booming operations resume. |
| **1971** | BC Hydro replaced the 1911 powerhouse, relocating it to the west side of the Jordan River. |
| **1972** | The last of the Pacific salmon species, pink salmon, were no longer observed spawning in the Jordan River. |
| **1977** | Main access tunnel to the mine collapsed and the mine became inactive. |
| **1993** | The Ministry of Mines officially closed the mine. Cominco received written confirmation that the property had been returned to the Crown, and all mineral claims associated with the Jordan River property had been surrendered to the Crown. |
| **2000 - 2001** | BC Hydro's Water Use Planning (WUP) process was initiated in the Jordan River. A consultative committee was assembled to engage stakeholders in the operational changes of the Jordan River Water Use Plan. |
| **2003** | The Comptroller of Water Rights revised the Jordan River WUP in 2003 under the provincial *Water Act*. Several biological studies were initiated due to the WUP process. |
| **2008** | BC Hydro installed a fish water release pipe at the Elliot Dam, and an agreement was made through the Jordan River WUP to maintain a year-round base flow.<br>Western Forest Products sold off private portions of land base. |
| **2010** | Crown portions were formed into their own Tree Farm Licence (TFL 65) encompassing 20,213 hectares. |
| **2011** | The rights to TFL 65 were sold to Pacheedaht Anderson Timber Holdings Limited Partnership (PATH). PATH is a partnership between the Pacheedaht First Nations and Andersen Timber. Daily activities within TFL 65 are managed by their general partner, Queesto Community Forest Ltd, including booming operations of the dry land sort. Dredging occurs in the lower portion of the Jordan River every two years. |
| **2013** | Mineral rights to inactive copper mine have been purchased by private owners, and preliminary mineral exploration of the remaining copper ore bodies has been initiated. |
| **2014** | The Ministry of Environment ordered the current landowners, Western Forest Products, and previous mine owners, Teck Resources, to submit a site risk classification report pursuant to Protocol 12 of the *Contaminated Site Regulation.*<br>SNC Lavalin was retained by Teck Resources to conduct a Supplemental Stage 1 and Limited Stage 2 Preliminary Site Investigation (PSI) of the mining property in Jordan River. |
| **2017** | The local watershed-based group, Jordan Watershed Round Table, is founded in |

| | |
|---|---|
| | January and meets quarterly throughout the year. Teck Resources, SNC Lavalin, and the Ministry of Environment meet with the Jordan Watershed Round Table and discuss the results of the PSI in Jordan River, and plans for the Detailed Site Investigation (DSI). No remediation options for the mine were concluded at this point. |

***BC Hydro's Jordan River Water Use Plan***

The BC Hydro facilities in the Jordan River watershed are operated according to the WUP, including dam releases and fish flows. The Jordan River WUP process was initiated in April 2000 and completed in November 2001, where the operational changes to the Jordan River BC Hydro facilities in the WUP were based on recommendations of the Jordan River Use Plan Consultative Committee (BC Hydro, 2003). The committee was comprised of fourteen members that expressed interests in First Nation cultural use and heritage sites, power, recreation, water quality, fish and wildlife, and socio-economic aspects of the watershed (BC Hydro, 2002). The Comptroller of Water Rights revised the Jordan River WUP in 2003 under the provincial *Water Act* (BC Hydro, 2003). The proposed revised operating conditions in the WUP were expected to improve habitat for resident fish populations and increase the quality of ecological habitat downstream in lower Jordan River (BC Hydro, 2003). BC Hydro aimed to commit to a greater base flow that would increase salmonid success in the lower Jordan River by improving water temperature and water quality in the summer months (BC Hydro, 2003). In 2008, BC Hydro installed a fish water release pipe at the Elliot Dam, and an agreement was made through the Jordan River WUP to maintain a year-round base flow release of 0.25 cubic meters per second (Burt, 2012). Due to concerns of the release valve tripping, and potentially destroying downstream fish habitat, a decision was made to keep the valve of the release pipe in a locked open position, which resulted in a flow release of about 0.30 to 0.40 cubic meters per second from the Elliot Headpond (Burt, 2012). Prior to 2008, there was no base flow in the Jordan River, except when the dam was spilling during a flood event, which resulted in the downstream fish habitats dependent on tributary inputs (Burt, 2012). Flows in the Jordan River were as low as 10 – 12 liters per second (0.010 to 0.012 cubic meters per second) during the dry summer months (Burt & Hudson 2008, 2009). The lack of freshwater flows in the Jordan River heavily impacted downstream fish habitat and exacerbated cumulative effects of contamination from the abandoned mine site downstream.

The WUP outlined uncertainties and information gaps in the proposed operating procedures, and it was recommended that the Comptroller of Water Rights direct BC Hydro to implement a monitoring program that would reduce these uncertainties over time by assessing the outcomes of the operational changes and providing additional information that can be used to inform future operating decisions (BC Hydro, 2003). These uncertainties included a lack of information on establishing minimum base flows to increase downstream ecological habitats, specifically influencing river-bearing rainbow trout; metal toxicity from historic mining operations and critical low flows that may impact the success and survival of spawning and rearing salmonid species; response level of stress to reservoir rainbow trout associated with draw downs, and whether or not discharge reduction enhances surf quality on select weekends in March (BC Hydro, 2003). As a result, a number of projects have been actively conducted in the watershed since 2003 that focus on monitoring the uncertainties outlined in the WUP (Burt, 2006, 2007, 2008, 2009, 2010, 2011,2012; Cascadia Biological Services, 2006, 2007, 2009, 2010a, 2010b, 2011). A review of the Jordan River WUP is recommended to occur every six years (BC Hydro, 2003), but it was not until 2014 that BC Hydro announced that the provincial review of all the WUPs in the province was to commence January 2015 and conclude in 2030 (BC Hydro, 2015). Jordan River's WUP review is currently underway (BC Hydro, 2018).

***Cumulative Impacts on Salmon Habitat***

The Jordan River watershed once hosted native salmon runs of coho, pink, and chum that no longer exist at historical escapement levels due to the cumulative effects of multiple resource extraction activities and BC Hydro energy facilities that are present within the watershed (Wright & Guimond, 2003). The presence of these salmon runs held significant cultural importance to the Pacheedaht First Nation (BC Hydro, 2003). Resource extraction practices, such as forestry and mining, have been present in the watershed since the late 1800s. A dry land sort and log booming operation exists at the mouth of the Jordan River. Over the last few decades, research suggests that copper contaminants from an abandoned underground copper mine have been continuously leaching into the river and have contributed to the loss of aquatic life in the lower reaches of the Jordan River (Wright & Guimond, 2003). Biological reports initiated by the WUP indicate that contamination from the mine has affected and altered sensitive water quality parameters for a healthy fish habitat in Jordan River (Burt, 2012). Yet, there had not been an extensive water quality study conducted that examines the spatial and seasonal water quality extents of the mining contamination, specifically copper. Overall, it is clear that the cumulative effects of the copper contamination, and resource extraction activities from hydropower and forestry have led to detrimental impacts on fish habitat in the Jordan River.

***Local Water Governance Initiatives***

The Jordan River community was in the process of creating a watershed-based group (Hydro, 2016) which parallels a recent wide-spread emergence of community-based watershed governance initiatives in British Columbia (Brandes & O'Riordan, 2014; Moore & Baltutis, 2016; Morris & Brandes, 2013). There had been an emerging dialogue and initiation of informal organization for local interests to engage in water decision-making in the watershed. The 'Jordan Watershed Round Table,' was founded in January 2017, when interested community members, industry stakeholders, government agencies, and First Nations first met to create a mechanism for greater influence in water planning and governance processes in the Jordan River watershed. The motivations to create a local watershed-based group were similar to neighboring watersheds on Vancouver Island, like the Cowichan Watershed Board, and Shawnigan Watershed Roundtable (Hunter et al., 2014).

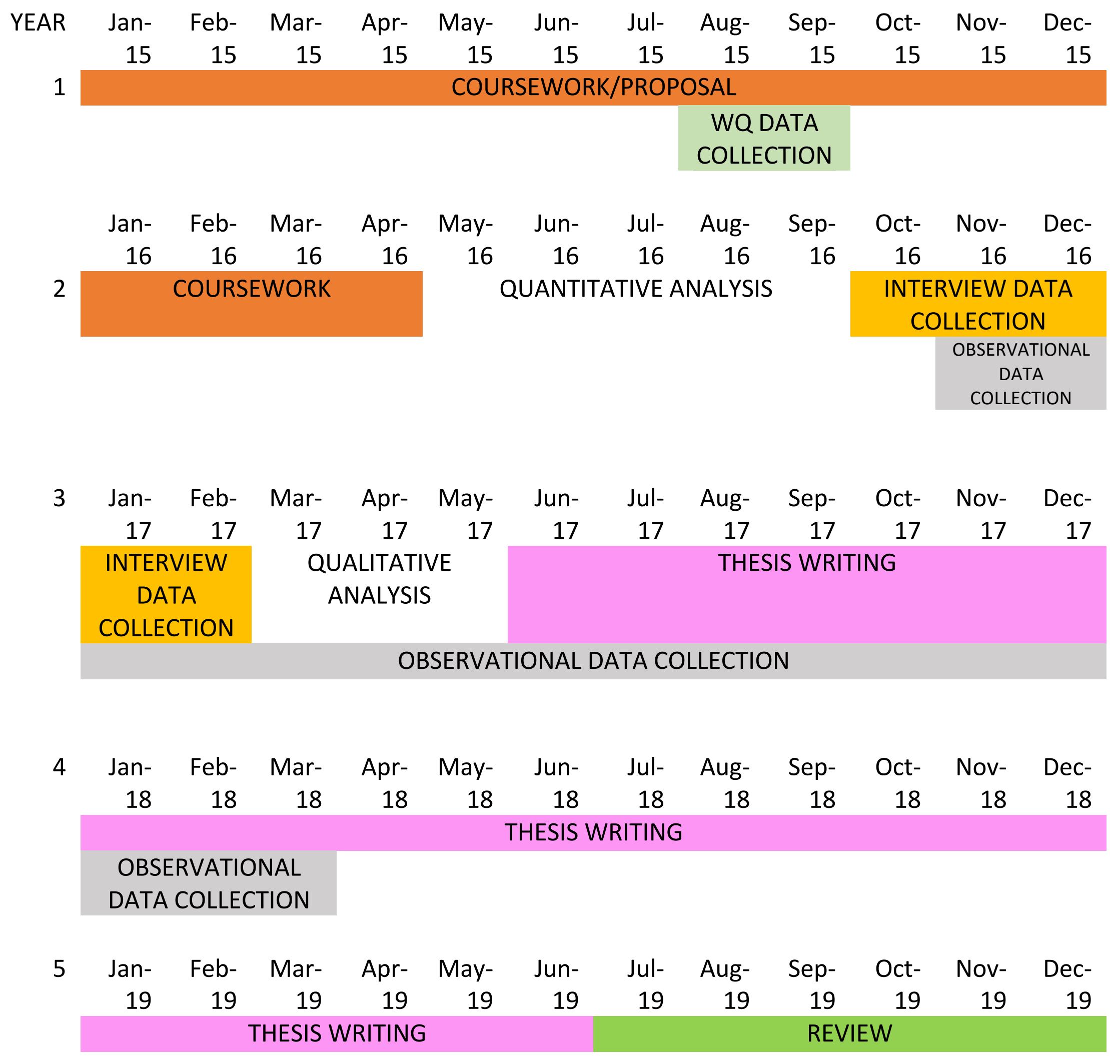
**Temporal Scope of the Case Study**

A dynamic and constantly evolving case, like the Jordan River watershed, poses challenges to a researcher during the stages of data collection and analysis (Baxter, 2010). For the purpose of this research, a temporal boundary was established from the mid-1960s, when water quality contamination was being recognized as a significant concern following the last observations of Pacific salmon stocks in the Jordan River watershed, through to the implementation of the Water Use Plan and initial stages of local water governance initiatives, including the last meeting attended by the researcher on March 15, 2018. This temporal time frame also indicates the date range at which reports, documents, and literature were published and used in the scope of this research project.

The quantitative data on water quality was collected August 2015 to September 2015 (refer to Chapter 2). The qualitative data, interview and observational data was collected from October 2016 to March 2018 (refer to Chapter 3). Specifically, interview data collection began October 2016 to February 2017, and observational data in the form of meetings attendance November 2016 through March 2018. March 2018 represents the end of the data collection period, which had been continually collected due to the dynamic context of the case during the thesis writing period. The thesis writing period began June 2017 and concluded June 2019. Figure 4 summarizes the timelines of thesis research project.

**Figure 4**

*Thesis Research Timeline*




There are changes to the watershed planning and governance regime in the Jordan River watershed that are ongoing. The DSI data was in the initial planning stages, and remedial options for the mine had not yet been confirmed until May 2019 near the end of the thesis writing period. The Jordan River WUP was under review in 2018 and consultations with First Nations and the public were ongoing. Contrastingly, the quantitative water quality data gathered in the Jordan River watershed is expected to remain reflective of the current state in the Jordan River until remedial options have been prescribed and applied to the mine. As a result, events and changes after March 2018 were not included as a part of this research. Regardless of the temporal constraints of this research, the Jordan River watershed findings will still provide relevant insights into watershed planning and governance processes currently underway across British Columbia, Canada, and elsewhere.

**Data Collection Methods: A Mixed Methods Approach**

Mixed methods research combines the strengths of both qualitative and quantitative approaches to understand research problems holistically through triangulation (Creswell, 2008). The data is collected, integrated and disseminated using both methods of qualitative and quantitative inquiry (Creswell, 2008). The data in mixed methods can be used to provide additional information in a study and enhance a larger data set within a more focused data set (Creswell, 2008).

This research project has collected qualitative data that focuses on the capacity of watershed governance from various actors through methods of interviewing that are enhanced with a more focused data set of quantitative water quality data that outlines primary issues of environmental concerns in the Jordan River watershed. Moreover, case study methodology accommodates flexibility for mixed methods research (Mingers & Brocklesby, 1997). An advantage of using a mixed methods approach is that the research reaches and captures the interests of an increasingly wider audience from a number of diverse disciplines (Creswell, 2008), which parallels suitably with the foundations of geography research.

The scope of this research focuses on examining the issues of concern for the local community in the Jordan River and assessing the impact of the Water Use Planning process to create capacity for watershed governance initiatives. To accomplish this, the study adopted a mixed methods approach: quantitative analysis of water quality issues (refer to Chapter 2 for methodology), and qualitative analysis of watershed governance capacities using semi-structured interview and observational data gathered from participation in local meetings relevant to the research project (refer to Chapter 3 for methodology). An overall document review was conducted to provide a baseline, cross-examine and verify the quantitative and qualitative data in this research project.

## Research Positionality

Social science qualitative research supports stating the researcher's positionality as it is critical in ensuring the validity of the research project (Corlette & Mavin, 2018). The researcher's personal, professional and intellectual positionalities may cohere or diverge with the context of the research (Corlette & Mavin, 2018). In this section, I state my positionality as the researcher and discuss the precautionary approaches taken to limit bias and subjectivity in the research.

### An Opportunity to Influence Change

The motivation behind almost every graduate student is to influence change. It is the very thought of influencing change that keeps a graduate student focused and fueled on a Friday night in front of their double screens (hence tonight of a brisk March evening in Haida Gwaii). This was truly the motivation behind my graduate work in the Jordan River, and an opportunity to give back. It all started when I was sixteen years old, a fresh new 'N' driver with her mom's 1989 Dodge Caravan that I realized I had the freedom to escape and explore at the tip of my toes on a gas pedal. I had become bored with my one-acre backyard on top of a rural unlogged mountain and wanted to venture a little deeper along the coast. I grew up in a small commercial fishing and logging town called Sooke on Vancouver Island, British Columbia. My dad was an ex-federal marine engineer with the Canadian Coast Guard, a seasoned coastal mariner. I grew up with him in a foam mustang lifejacket bobbing around in the back of my Grandpa's 20-foot aluminum hull Silver Streak boat covered in crab guts, sun-kissed, and smelling like a fish out of water. At a young age salmon became a very important aspect of my life. It became part of my culture. It became part of my identity. It became my connection to place.

The Sooke River is home to a large Chinook salmon run that joins the Washington Tyees in the Juan De Fuca Strait and schools north to the unknown until they have been traced in the hulls of fisherman in places like Haida Gwaii and Alaska. I grew up in grade school reciting the life cycle of the Pacific salmon before I could spell and then found myself twenty-five years later in full-duty uniform quietly stalking along the banks of the lush old-growth rainforests of Haida Gwaii in search of these salmon and their illegal human predators. In between there, during my young free age of sixteen, I stepped foot along the boulders of the Jordan River, when I finally stumbled across the abandoned mine that I heard rappelers rave about when I was buying my first new pair of Keen hiking boots at Valhalla Outfitters.

With a few locally sourced hints, I hiked an old logging road through an awkward overgrown gravel pit located along the east side of Jordan River. I found a rope wrapped around the base of a flagged cedar tree and followed it straight down a very steep cliff. The rope led me to the open mine portal on the side of the cliff. The giant hole drilled into the bedrock still had railway tracks coming out of it and an old wooden ladder to climb down into it. To my surprise, there were two young fellows gearing up with headlamps at the entrance. They were rappelling down the flooded elevator shaft they told me, where they heard that the river flows through the bottom of the mine. They were nervously laughing because not many people had done it before, and they gave me their names in case they didn't return.

I continued on since it was a sweltering hot day and attempted to climb down the cliff towards the river. When I finally stepped out of the thick trail at the base of the cliff, I couldn't believe what I saw. There was mining equipment, tools and rusted steel pipes strewn across the river. The beautiful clear waters that pooled and waterfalled down the incredible canyon washed over decades of heavy debris in the channel. I began to collect these round steel balls that came in all sizes and were heavy, and rusted, nestled between the boulders. Later I learned that these balls were used to crush mine tailings and tease out the copper in a mixture of toxic chemicals. As I ventured deeper along the riverbanks, I noticed old foundations of houses, roads, bridges, railway tracks and other mine access tunnels that whistled cold air and had been partially blocked with large wooden beams. There were old vehicles, cables, ditches, and piles of iron-stained crusted gravels that stood over 100 feet high that were sloughing into the river. The one observation of the river that stuck with me the most was - there was no life. In my lifetime growing up swimming and snorkeling in the healthy Sooke River, I have never encountered a river yet that didn't have little salmon fry, or stick bugs scooting over the river rocks. I went home that night, a little confused on what I had seen, twigs tangled in my curly blonde hair and scuffed up knees. My mom scolded me for being out all day and told me to wash up for dinner.

I grew up doing my final year of high school math homework next to my surfboard at a picnic table at the mouth of the Jordan River. The view was of the ocean, and I sat amongst the loggers at lunch hour in front of a fry-shack, the famous "Shakies", that served deep-fried clam strips, burgers, milkshakes and cookie-dough treats called "surf balls". I loved the waterfront of Jordan River, provincial parks nearby, and the surf culture of the locals. I remained curious about what I had observed in the Jordan River, and found myself researching the mine throughout my undergraduate studies in Geography at the University of Victoria. Over a few family dinner conversations between final exams, my father eventually learned that I had visited the mine first-hand and told me that the copper mine had killed off all the salmon in the Jordan River. My father, being the avid fisherman that he is, was very passionate about salmon and well educated on the topic of fisheries due to his experience with his Canadian Coast Guard career up and down the coast of British Columbia.

During my undergraduate degree, I decided to become more intimate with the little hamlet of Jordan River and landed a part-time job at a local oceanfront café. My motivations for the job were to get to know the locals a little better and see if I could find out more information about the contaminated mine that was sitting abandoned on the slopes of the Jordan River. I was in full force of my second-year university, playing on a competitive softball team, and working part-time as an Assistant Aquatic

Coordinator at a local recreation center in Sooke. Technically, I wasn't there for the money, but wanted to innocently probe the right people and begin plotting a path to influence change in Jordan River.

During my short waitressing career in Jordan River, I served an old family friend who had coached me in softball years earlier. I learned that he was a mineral explorationist that hired students for summer gigs to collect soil and water samples in the Arctic and in remote areas across Canada. Ironically, I was studying earth sciences, geochemistry and geology at the University of Victoria and I found the confidence to ask him for a job. Four weeks later, I found myself on the Arctic tundra amongst thousands of migrating caribou as I collected water and soil samples for diamond exploration by helicopter. I continued to work as a mineral explorationist for the following two years in places like northern Vancouver Island, northern British Columbia, Northwest Territories and Nunavut.

Towards the end of my mineral exploration career, I began to realize what effect mining has on the landscape and the role that I was playing in it. I often reminisced about the evenings that I sat on top of an esker and watched the northern sun set across the Arctic tundra. I would think about the wildlife that called the tundra 'home', including the pack of beautiful white arctic wolves that stalked me in a stream, the charging caribou that flanked from the herds of thousands migrating across the tundra, the bravery exerted by the musk-ox as they formed a circle around their young when we flew over, and the wolverine that was spooked out of its den by our helicopter. My undergraduate studies at the University of Victoria, had shifted into a resource management focus, and I knew that there was always a more sustainable route for resource extraction. As time was progressing, so were the modern approaches to sustainable resource practices. I remember having a conversation about these mixed feelings with my mineral exploration boss nearing the end of my undergraduate degree. I distinctly remember a quote that he had said "you may feel that way but – it's always good to have the experience on both sides". I realized that what I had learned in mineral exploration was valuable and I could use those skills in combination with my education to influence change and sustainability in an area that I was passionate about. My thoughts immediately traced back to the case in the Jordan River.

These experiences shaped my perspective and motivated my desire to explore avenues for sustainable resource practices that foster cooperation, collaboration, and transparency in structured participatory decision-making processes that incorporate input from an inclusive range of watershed actors. Therefore, watershed governance was key to defining the processes and institutions through which water-related decisions are made in the Jordan River watershed. I proposed my project to Dr. Michele-Lee Moore, leader of the Water, Innovation, and Global Governance Lab at the University of Victoria. The Jordan River was at a politically contentious time, where the river had sat contaminated since the concerns were voiced on the WUP consultative committee and nothing had been done in the meantime. The locals were becoming restless and advocating for action. There were conversations about forming a watershed-based group similar to neighboring watersheds, such as the Cowichan Watershed Board and the Shawnigan Watershed Roundtable. In addition, there had not been funding or any designated responsibility to complete a full water quality study that evaluated the extent of the contamination from the copper mine. The Jordan River was in a transitional state of shifting from a water management process, such as the WUP, to local watershed governance initiatives as the community began to assemble a watershed-based group to address the remnant concerns of resource extraction practices in the watershed.

**Approaches to Limiting Bias and Subjectivity**

Throughout my research, I made a continuous effort not to imply bias or subjectivity to my research. I continually practiced “reflexivity”, where I self-monitored and self-responded to my thoughts and feelings throughout the research (Corlette & Mavin, 2018; Macbeth, 2001). I continually reflected by reviewing notes of certain data that may have been vulnerable to my assumptions or perceptions of my positionality, and attempted to only extract concrete conclusions that contributed to the research from a decentered non-bias position as the researcher (Grbich, 2016; Macbeth, 2001). My goal with this research, was to accurately reflect the current dynamics, successes and challenges in water governance by being as objective as possible. It is not beneficial to bias data based on anecdotal evidence or passions which would be unhelpful to social science research and the validity of my research project.

**Summary**

Historically, supply-management perspectives have dominated water policy in recent history through the belief that nature could be shaped to suit the needs of society, and that water was never a limiting factor of growth in the face of resource extraction (Brandes et al., 2007; Sprague, 2007). Ecological and social concerns have not always been considered in water policy until recent history (Muldoon & McClenaghan, 2007). As a result of these policy practices, communities within watersheds are unable to cope with the pressures generated by development. Communities are faced with water challenges like droughts, rapid resource development, and contaminated drinking water. It is clear that an overarching 'blanket' policy approach is not effective or efficient in addressing these challenges.

Over the last decade, Canadian water policy has changed significantly to include approach to "moments" of improved transparency in governance, such as increasing public participation and introducing new policy initiatives by provinces (Renzetti & Dupont, 2017). In British Columbia, new legislation has incorporated ecological values into water policy (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017) and opportunities for planning and governance at a localized level (Brandes & Simms, 2018; Curran & Brandes, 2017). Overall, there is growing agreement that watershed collaboration at a local level could be key to defining solutions.

In British Columbia, the *WSA* has offered an opportunity to delegate select governance responsibilities to local watershed institutions (Brandes & O'Riordan, 2014; Brandes & Simms, 2018), but it is unclear which watershed-based institutions have the capacity to take on these new provisions. Questions remain on whether these local watershed-based institutions can be evaluated at an early stage of the watershed organization being created, like the Round Table being formed in the Jordan River watershed.

**Chapter One References**

Armitage, D., de Loë, R. C., Morris, M., Edwards, T. W. D., Gerlak, A. K., Hall, R. I., … Wolfe, B. B. (2015). Science–policy processes for transboundary water governance. *Ambio*, *44*(5), 353–366. https://doi.org/10.1007/s13280-015-0644-x

Bakker, K. (2007a). Commons or Commodity? The Debate over Private Sector Involvement in Water Supply. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 185–204). UBC Press.

Bakker, K. (2007b). Introduction. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 1–20). UBC Press.

Bakker, K., & Cook, C. (2011). Water Governance in Canada: Innovation and Fragmentation. *International Journal of Water Resources Development*, *27*(2), 275–289. https://doi.org/10.1080/07900627.2011.564969

Barry, K. L., Grout, J. A., Levings, C. D., Nidle, B. H., & Piercey, G. E. (2000). Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(10), 2032–2043. https://doi.org/10.1139/f00-157

Baxter, J. (2010). Case Studies in Qualitative Research. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography* (pp. 81–98). Oxford University Press: Canada.

BC Hydro. (2002). *Executive Summary: Jordan River Water Use Plan Consultative Committee Report*. https://doi.org/10.1007/s00247-002-0666-y

BC Hydro. (2003). *Jordan River Water Use Plan*.

BC Hydro. (2015). *Water Use Plan Orders Review Program*. Retrieved from https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/gds14-303c-wupor-project-update-med-res.pdf

BC Hydro. (2018). Jordan River Water Use Plan. Retrieved December 10, 2018, from https://www.bchydro.com/toolbar/about/sustainability/conservation/water_use_planning/vancouver_island/jordan_river.html

Bhuiyan, M. A. H., Parvez, L., Islam, M. A., Dampare, S. B., & Suzuki, S. (2010). Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. *Journal of Hazardous Materials*, *173*(1–3), 384–392. https://doi.org/10.1016/j.jhazmat.2009.08.085

Blatter, J. (2008). Case Study. In L. Givens (Ed.), *The SAGE Encyclopedia of Qualitative Research Methods* (pp. 69–71). https://doi.org/10.4135/9781412963909

Booth, A. L., & Skelton, N. W. (2011). "You spoil everything!" Indigenous peoples and the consequences of industrial development in British Columbia. *Environment, Development and Sustainability*, *13*(4), 685–702. https://doi.org/10.1007/s10668-011-9284-x

Brandes, O. M., Brooks, D., & M'Gonigle, M. (2007). Moving Water Conservation to Centre Stage. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 281–300). UBC Press.

Brandes, O. M., & O'Riordan, J. (2014). *A Blueprint for Watershed Governance in British Columbia*.

Brandes, O. M., & Simms, R. (2018). *Advancing Freshwater Protection: Tools and Opportunities in British Columbia's Water Sustainability Act*.

Burke, H. G. (2012). *Sunro Copper Mine Restart Project*. Retrieved from http://www.sunrocopper.ca/index.htm

Burt, D. W. (2006). *Lower Jordan River fish index study - year 1 results (2005)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2007). *Lower Jordan River fish index study - year 2 results (2006)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2008). *Lower Jordan River fish index study - year 3 results (2007)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2009). *Lower Jordan River fish index study - year 4 results (2008)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2010). *Lower Jordan River fish index study - year 5 results (2009)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2011). *Lower Jordan River fish index study - year 6 results (2010) and pre/post flow release.* Prepared for BC Hydro, Water Use Planning,

*comparisons (DRAFT)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. (2012). *Summary of Water Quality and Biological Data for Anadromous Reaches of the Jordan River*. Prepared for BC Hydro, Water Use Planning

Burt, D.W., and R. Hudson. (2008)*. Lower Jordan River inflow monitoring: Year 2 results (2007-2008)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC. 44 p.

Burt, D.W., and R. Hudson. (2009). *Lower Jordan River inflow monitoring: Year 3 results (2008-2009)*. BC Hydro, Water Use Planning, Burnaby, BC. 40 p.

Capital Regional District. (2014). *Shirley-Jordan River Official Community Plan ROUGH DRAFT*. Retrieved from https://www.crd.bc.ca/docs/default-source/jdf-pdf/shirley-jordan-river-ocp/pps-jdf-2014-09-01-sjr-roughdraft-2.pdf?sfvrsn=2

Cascadia Biological Services. (2006). *Jordan River spawning assessment and enumeration, Year 1 (Sept 2005 - May 2006): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2007). *Jordan River spawning assessment and enumeration, Year 2 (Sept 2006 - May 2007): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2009). *Jordan River spawning assessment and enumeration, Year 3 (Sept 2007 - May 2008): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010a). *Jordan River spawning assessment and enumeration, Year 5 (Sept 2009 - May 2010): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010b). *No TitleJordan River spawning assessment and enumeration, Year 4 (Sept 2008 - May 2009): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Cascadia Biological Services. (2011). *Jordan River spawning assessment and enumeration, Year 6 (Sept 2010 - May 2011): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Christensen, R., & Lintner, A. (2007). Trading Our Common Heritage? The Debate over Water Rights Transfers in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 219–241). UBC Press.

Cohen, A., & Davidson, S. (2011). The watershed approach: Challenges, antecedents, and the transition from technical tool to governance unit. *Water Alternatives*, *4*(1), 1–14.

Corlette, S., & Mavin, S. (2018). Reflexivity and Researcher Positionality. In *The SAGE Handbook of Qualitative Business and Management Research Methods: Methods and Challenges* (pp. 377–398). https://doi.org/10.4135/9781526430236

Creswell, J. (2008). Mixed Methods Research. In L. Givens (Ed.), *The SAGE encyclopedia of qualitative research methods* (pp. 527–529). https://doi.org/10.5860/CHOICE.46-4214

Curran, D. (2017). Leaks in the system: Environmental flows, aborignial rights, and the modernization imperative for water law in British Columbia. *University of British Columbia Law Review*, *50*(2), 233.

Curran, D. (2019). Indigenous processes of consent: Repoliticizing water governance through legal pluralism. *Water (Switzerland)*, *11*(3). https://doi.org/10.3390/w11030571

Curran, D., & Brandes, O. M. (2017). Changing Currents: A Case Study in the Evolution of Water Law in Western Canada. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (pp. 45–68). Springer International Publishing.

Curran, D., & Mascher, S. (2016). Adaptive Management in Water Law: Evaluating Australian (New South Wales) and Canadian (British Columbia) Law Reform Initiatives. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3007790

De Loe, R., & Kreutziser, R. (2007). Challenging the Status Quo: The Evolution of Water Governance in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 85–103).

Ellis, D. (2008). The Role of Deep Submarine Tailings Placement (STP) in the Mitigation of Marine Pollution for Coastal Island Mines. *Marine Pollution: New Research*, 23–51.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*. https://doi.org/10.1177/1077800405284363

Foerster, A. (2011). Developing Purposeful and Adaptive Institutions for Effective Environmental Water Governance. *Water Resources Management*, *25*(15), 4005–4018. https://doi.org/10.1007/s11269-011-9879-x

Fraser Basin Council. (2011). *Rethinking Our Water Ways: A guide to water and watershed planning for BC communities in the face of climate change and other challenges*. Retrieved from https://www.rethinkingwater.ca/_Library/docs/FBC_WaterGuide_FINAL.pdf

Fraser Basin Council. (2014). *Indicators to Assess Watershed Health in British Columbia DRAFT Discussion Paper*.

Fraser Basin Council. (2016). *Advancing Sustainability Solutions Throughout British Columbia: Strategic Plan 2016-2021*. Retrieved from https://www.fraserbasin.bc.ca/_Library/About_Us/2016-21_strategic_plan.pdf

Garrick, D. (2017). Water Security and Adaptation to Climate Extremes in Transboundary Rivers of North America. In D. P. Dupont & S. Renzetti (Eds.), *Water Policy and Governance in Canada* (p. 121). Springer International Publishing.

Grbich, C. (2016). The Position of the Researcher. *New Approaches in Social Research*, 67–79. https://doi.org/10.4135/9781849209519.n5

Gregory, R., Failing, L., & Higgins, P. (2006). Adaptive management and environmental decision making: A case study application to water use planning. *Ecological Economics*, *58*(2), 434–447.

https://doi.org/10.1016/j.ecolecon.2005.07.020

Gullason, K. (2018). The Water Sustainability Act, Groundwater Regulation, and Indigenous Rights to Water: Missed Opportunities and Future Challenges. *Appeal: Review of Current Law and Law Reform*, *23*, 29.

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., … Bergsma, E. (2010). The Adaptive Capacity Wheel: A method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science and Policy*, *13*(6), 459–471. https://doi.org/10.1016/j.envsci.2010.05.006

Harvey, B., & Greer, D. (2004). Reality Stewardship: Survival of the fittest for community salmon groups. In *Pacific Fisheries Resource Conservation Council*.

Hill, C, Furlong, K., Bakker, K., & Cohen, A. (2008). Harmonization Versus Subsidarity in Water Governance: A Review of Water Governance and Legislation in Canadian Provinces and Territories. *Canadian Water Resources Journal*, (33), 315–333.

Hill, Carey, Furlong, K., Bakker, K., & Cohen, A. (2008). Harmonization versus subsidiarity in water governance: a review of water governance and legislation in the canadian provinces and territories. *Canadian Water Resources Journal*, *33*(4), 315. Retrieved from http://uvic.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMw3V1dT9swFLUYT9vDxNjGGCD5iReUKbabJkHioaAheEJooD1WqXNdVXSplLRC_Ij9Z-61HSct6h_grY2bD8Wn9v0491zGlPwVRxtrgpSQDnUCuUliaQZgMikGWgrQOX63Cd5eNdlO21CsO_YeJv6mqPEOvrzyjFgXq-aswfVhhlCgVnUU4nguSBxxahvt0ry7mu

Hunter, R., Brandes, O. M., & Moore, M. (2014). *A Watershed Governance Case Study. The Cowichan Watershed Board : An Evolution of Collaborative Watershed Governance*.

Hurlbert, M., & Gupta, J. (2016). Adaptive Governance, Uncertainty, and Risk: Policy Framing and Responses to Climate Change, Drought, and Flood. *Risk Analysis*, *36*(2), 339–356.

https://doi.org/10.1111/risa.12510

Hydro, B. (2016). Planning to Improve Fish Habitat on Jordan River. Retrieved April 18, 2016, from Fish and Wildlife Program website: http://fwcp.ca/project/planning-to-improve-fish-habitat-on-jordan-river/

International Union for Conservation of Nature. (2009). *Reforming Water Governance* (A. Iza & R. Stein, Eds.). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=37D0786A768B3C387D5A816B6BB30676?doi=10.1.1.732.7510&rep=rep1&type=pdf

Joe, N., Bakker, K., & Harris, L. M. (2017). *Perspectives on the BC Water Sustainability Act: First nations respond to water governance reform in British Columbia*. https://doi.org/10.13140/RG.2.2.14041.31840

Johns, R., Chan, C., Gunardi, A., & Felker, A. (2014). *Treatment of Woodwaste Landfill Leachate Using Engineered Wetlands: Jordan River*. Retrieved from http://www.bceia.com/media/61764/jordanriverwetlands.pdf

Kebo, S., & Bunch, M. J. (2013). Canadian ENGOs in governance of water resources: information needs and monitoring practices. *Environmental Monitoring and Assessment*, *185*(11), 9451–9460. https://doi.org/10.1007/s10661-013-3264-6

Lautze, J., De Silva, S., Giordano, M., & Sanford, L. (2011). Putting the cart before the horse: Water governance and IWRM. *Natural Resources Forum*, *35*(1), 1–8. https://doi.org/10.1111/j.1477-8947.2010.01339.x

Macbeth, D. (2001). On “Reflexivity” in Qualitative Research: Two Readings, and a Third. *Qualitative Inquiry*, *7*(1), 35–68. https://doi.org/10.1177/107780040100700103

Matthews, C., Gibson, R., & Mitchell, B. (2007). Rising Waves, Old Charts, Nervous Passengers: Navigating Toward a New Water Ethic. In *Eau Canada: The Future of Canada’s Water* (pp. 335–

358).

McDaniels, T. L., Gregory, R. S., & Fields, D. (1999). *Democratizing risk management: Successful public involvement in local water management decisions*. *19*(3), 497–510.

Messerli, B., Viviroli, D., & Weingartner, R. (2004). Mountains of the world: Vulnerable water towers for the 21 st century. *Ambio*, *33*(SPEC. ISS. 13), 29–34.

Mingers, J., & Brocklesby, J. (1997). Multi-methodology: Towards a framework for mixing methodologies. *International Journal of Management Science*, *25*(5), 489–509.

Mitchell, B. (2009). IWRM In Practice: Lessons From Canadian Experiences. *Journal of Contemporary Water Research & Education*, *135*(1), 51–55. https://doi.org/10.1111/j.1936-704X.2006.mp135001006.x

Mitchell, B. (2017). The Hydrological and Policy Contexts for Water in Canada. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (pp. 13–28). Springer International Publishing.

Molle, F. (2009). Water, politics and river basin governance: repoliticizing approaches to river basin management. *Water International*, *34*(1), 62–70. https://doi.org/10.1080/02508060802677846

Moore, M.-L., & Baltutis, J. (2016). Assessing capacity in watershed organizations in British Columbia: A study of reliability and resilience in organizational processes. *Canadian Water Resources Journal*, *1784*(May), 1–13. https://doi.org/10.1080/07011784.2015.1137230

Moore, M.-L., Shaw, K., & Castleden, H. (2018). We Need More Data! *Water Alternatives*, *11*(1), 142–162. Retrieved from https://poliswaterproject.org/files/2018/02/Art11-1-8.pdf

Morris, B. T., & Brandes, O. M. (2013). *The State of the Water Movement in British Columbia: A Waterscape Scan & Needs Assessment of B.C. Watershed-Based Groups*. (July), 46. Retrieved from http://polisproject.org/files/pub_database/stateofwatermovement_lowres.pdf

Muldoon, P., & McClenaghan, T. (2007). A Tangled Web: Reworking Canada's Water Laws. In K. Bakker

(Ed.), *Eau Canada: The Future of Canada's Water* (pp. 245–261). UBC Press.

Nelitz, M., Murray, C., Porter, M., & Marmorek, D. R. (2006). Managing Pacific salmon for Ecosystem Values: Ecosystem Indicators and the Wild Salmon Policy. In *Pacific Fisheries Resource Conservation Council*.

Nowlan, L. (2007). Out of Sight, Out of Mind? Taking Canada's Groundwater for Granted. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 55–83). UBC Press.

Nowlan, L. (2010). CPR for Canadian Rivers — Law to Conserve , Protect , and Restore Environmental Flows in Canada. *Journal of Environmental Law and Practice*, *23*(November), 237–286.

Okanagan Water Stewardship Council. (2008). *Okanagan Sustainable Water Strategy: Action Plan 1.0*. Retrieved from https://www.obwb.ca/fileadmin/docs/osws_action_plan.pdf

Pacific Fisheries Resource Conservation Council. (2006). Selection and use of indicators to measure the habitat status of wild Pacific Salmon. In *Pacific Fisheries Resource Conservation Council*. Retrieved from https://www.psf.ca/sites/default/files/lib_12.pdf

Palmer, M. A., Bernhardt, E. S., Schlesinger, W. H., Eshleman, K. N., Foufoula-Georgiou, E., Hendryx, M. S., … Wilcock, P. R. (2010). Mountaintop Mining Consequences. *Science*, *327*(5962), 148–149. Retrieved from http://www.jstor.org.ezproxy.library.uvic.ca/stable/40508802

Parfitt, B., Batutis, J., & Brandes, O. M. (2012). *From Stream to Steam: Emerging Challenges for B.C.'s Interlinked Water and Energy Resources*.

Place, J., & Hanlon, N. (2011). Kill the lake? kill the proposal: Accommodating First Nations' environmental values as a first step on the road to wellness. *GeoJournal*, *76*(2), 163–175. https://doi.org/10.1007/s10708-009-9286-5

POLIS with Columbia Basin Trust and Living Lakes Canada. (2018). *Community Engagement in Watershed Governance : Case Studies and Insights from the Upper Columbia River Basin*. University of Victoria, BC.

Reed, M. G., & Bruyneel, S. (2010). Rescaling environmental governance, rethinking the state: A three-dimensional review. *Progress in Human Geography*, *34*(5), 646–653. https://doi.org/10.1177/0309132509354836

Renzetti, S., & Dupont, D. P. (2017). *Water Policy and Governance in Canada*. https://doi.org/10.1007/978-3-319-42806-2

Robinson, C. J., Bark, R. H., Garrick, D., & Pollino, C. A. (2015). Sustaining local values through river basin governance: community-based initiatives in Australia's Murray-Darling basin. *Journal of Environmental Planning and Management*, *58*(12), 2212–2227. https://doi.org/10.1080/09640568.2014.976699

Schindler, D. (2007). Foreword. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. xi–xiv). UBC Press.

Scodanibbio, L. (2011). Opening a policy window for organisational change and full-cost accounting: The creation of BC Hydro's water use planning program. *Ecological Economics*, *70*(5), 1006–1015. https://doi.org/10.1016/j.ecolecon.2010.12.022

Shrubsole, D., & Draper, D. (2007). On Guard for Thee? Water (Ab)uses and Management in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water*. UBC Press.

Smart, A. (2014, December 12). Meeting Little Comfort for Jordan River Dam's Path. *Times Colonist*. Retrieved from https://www.timescolonist.com/news/local/meeting-little-comfort-for-jordan-river-residents-in-dam-s-path-1.1664167

SNC Lavalin. (2016). *Supplemental Stage 1 and Limited Stage 2 Preliminary Site Investigation and Preliminary Risk Opinion - Sunro Mine, Jordan River, BC*.

Sprague, J. (2007). Great Wet North? Canada's Myth of Water Abundance. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 23–35). UBC Press.

Taylor, B., Loë, R. de, Bjornlund, H., de Loë, R. C., & Bjornlund, H. (2013). Evaluating knowledge production in collaborative water governance. *Water Alternatives*, *6*(1), 42–66. Retrieved from http://uvic.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMw3V09T8MwELVKJxgQFCoKRcrEEqXKh2MnA0NbFVWCDSrGyHHOFaikqAV-P3bsxKXthJgY40TKx73c-dl37xCKwoHvbfkENQ1hWDASg4wIRR5CHAOT0SnglEWVlOdGNVmrTmKyY__B8BOj313O3ft6wUzVAxRaJ1aX-TXG_wL3mSmhRN10t8HAa90dRp0bLsyy4Z

Teck Resources Limited. (2014). Elk Valley Water Quality Plan. In *Report to British Columbia Minister of Environment*.

Tsolum River Restoration Society. (2016). *Tsolum River Recovery Plan: Tsolum River Watershed*. Retrieved from https://www.tsolumriver.org/uploads/4/0/5/7/4057952/tsolum_river_recovery_plan-vaug2016.pdf

Vandecasteele, I., Marí Rivero, I., Sala, S., Baranzelli, C., Barranco, R., Batelaan, O., & Lavalle, C. (2015). Impact of Shale Gas Development on Water Resources: A Case Study in Northern Poland. *Environmental Management*, *55*(6), 1285–1299. https://doi.org/10.1007/s00267-015-0454-8

Venkateswarlu, K., Nirola, R., Kuppusamy, S., Thavamani, P., Naidu, R., & Megharaj, M. (2016). Abandoned metalliferous mines: ecological impacts and potential approaches for reclamation. *Reviews in Environmental Science and Biotechnology*, *15*(2), 327–354. https://doi.org/10.1007/s11157-016-9398-6

Viviroli, D., Dürr, H. H., Messerli, B., Meybeck, M., & Weingartner, R. (2007). Mountains of the world, water towers for humanity: Typology, mapping, and global significance. *Water Resources Research*, *43*(7), 1–13. https://doi.org/10.1029/2006WR005653

Walkem, A. (2007). The Land Is Dry: Indigenous People, Water and Environmental Justice. In K. Bakker (Ed.), *Eau Canada: The Future of Canada’s Water* (pp. 303–319). UBC Press.

*Water Sustainability Act.* SBC, (2014). c 15 http://www.bclaws.ca/civix/document/id/complete/statreg/14015

World Resources Institute. (2003). World Resources 2002–2004: Decisions for the Earth: Balance, Voice and Power. Retrieved from www.wri.org/wr2002

Wright, M. C., & Guimond, E. (2003). *Jordan River Pink Salmon Incubation Study*.

Yin, R. K. (2009). Case Study Research: Design and Methods. In L. Bickman & D. J. Rog (Eds.), *Essential guide to qualitative methods in organizational research*. https://doi.org/10.1097/FCH.0b013e31822dda9e

# Chapter Two: Riding the Wake of Resource Extraction Practices in Watersheds of British Columbia


## Abstract

Watersheds burdened by water quality issues caused by resource extraction operations are unable to cope with the competing pressures of climate change and resource development in British Columbia. This study examines the case of Jordan River in British Columbia, Canada – a watershed that is heavily influenced by resource extraction activities including mining, forestry and hydropower. Biological monitoring initiated by BC Hydro's Water Use Planning (WUP) process in the early 2000s suggests that contamination from an inactive copper mine has affected and altered sensitive water quality parameters for a healthy Pacific salmon habitat in Jordan River. Yet, there has not been an extensive water quality study conducted that examines the spatial or seasonal water quality extents of the mining contamination in Jordan River, specifically copper. This study explores how resource operations have affected freshwater quality in the Jordan River watershed. The first phase of this study includes a document review of relevant literature, and the second phase of the study focuses on examining the water quality of the Jordan River. Water quality samples were collected over a five-week period from five sites on the Jordan River beginning in September and concluding in October of 2015 during the most sensitive periods of salmon spawning activity in the lower reaches of the Jordan River. Spatial and seasonal water quality trends were identified and concluded that copper is the primary contaminate affecting the productivity of a healthy salmon habitat in the Jordan River. Acid mine drainage (AMD) processes were identified throughout the water quality data and are strongly influenced by the proximity of existing mine waste piles sourced from an abandoned copper mine, unnatural anthropogenic flows from the three BC Hydro dams present in the river system, in combination with the wet coastal climate in the Jordan River watershed. Furthermore, the three BC Hydro reservoirs on the Jordan River system further complicate the cycling and transport of dissolved organic carbon (DOC),

which plays an essential role in balancing aquatic chemistry as it can combine with other metals and nutrients, and buffer toxicity to freshwater aquatic life. Overall, it is recommended that the waste rock and tailings piles be physically removed and stabilized to reduce further impact of erosion and mass movement. The placement of organic debris dams in the lower reaches of the Jordan River would aid in the accumulation and retainment of DOC, and overall resiliency of the river system. BC Hydro's Water Use Plan reviews offer an opportunity to negotiate operations of the powerhouse and flow releases in the lower Jordan River to support a healthy Pacific salmon habitat. Water quality concerns in the Jordan River has resulted in the creation of the Jordan Watershed Round Table (JWRT), which will aid in open discussions and collaboration on rebuilding a healthy Pacific salmon habitat in Jordan River. Further research is recommended for long-term monitoring of the five sites outlined in the study during mine remediation and habitat restoration, in addition to establishing water quality objectives for the watershed.

## Introduction

In a growing number of watersheds across Canada, the pressures generated by multiple users and development have depleted available water and decreased overall resilience of aquatic ecosystems (De Loe & Kreutziser, 2007; Molle, 2009). While climate change is expected to have an impact on water quantity, it also will exacerbate water quality issues (Shrubsole and Draper 2007, Bakker and Cook 2011, Brandes and O'Riordan 2014). As just one example, contaminants and minerals will no longer be diluted with excess fresh water at certain times of the year and will negatively affect the water quality (Bakker and Cook 2011, Brandes and O'Riordan 2014). A growing concern with freshwater resources is that climate change is expected to exacerbate and affect not only the quantity, but quality of fresh water as well (Shrubsole and Draper 2007, Bakker and Cook 2011, Brandes and O'Riordan 2014). Contaminant and mineral concentrations will fluctuate erratically due to extreme variability of freshwater inputs caused by climate change and will overall negatively affect future water quality (Bakker and Cook 2011, Brandes and O'Riordan 2014).

Water quality has been identified as one of the top five water challenges in British Columbia's future (Simms & Brandes, 2016). Over the last decade in Canada, there has been significant attention given to strengthening provincial legislation for drinking water, including the ability to protect sources, monitoring, and reporting practices, especially following public outcry after the Walkerton Ontario tragedy in 2000, where contaminated tap water was responsible for several deaths and thousands of hospitalizations (Bakker & Cook, 2011). Yet, while drinking water standards have since improved on provincial scales (Bakker & Cook, 2011), ambient water quality challenges still remain problematic in sustaining freshwater ecosystem health (Dore, 2015; Mitchell, 2017; Simms & Brandes, 2016). A national freshwater assessment released in 2017, by WWF-Canada, analyzed 167 sub-watersheds across Canada, and found that "pollution is one of the most significant threats to Canada's rivers" (WWF-Canada, 2017). Pollution scored the highest as the most serious concern in 60 of the 167 sub-watersheds, and overall water quality degradation has led to habitat loss in 93 of the 167 sub-watersheds (WWF-Canada, 2017). Despite this assessment, the reality is that there is often an absence of data and information about water quality in watersheds (Moore, Shaw, & Castleden, 2018). In many watersheds across Canada and specifically in British Columbia, there has been intensive resource extraction activity in the recent past which no longer continues (Dore, 2015). For instance, mines may have halted operations, or forestry activities such as logging are no longer active. In Canada alone, it is estimated that over 10 000 abandoned mines exist and there is limited information on the impacts of these abandoned sites on water quality (Venkateswarlu et al., 2016). While many studies examine the water quality issues related to resource extraction activity while they are occurring (Bhuiyan, Parvez, Islam, Dampare, & Suzuki, 2010; Vandecasteele et al., 2015), but less is understood about how resource extraction continues to affect water quality long after it is stopped (Venkateswarlu et al., 2016).

This study examines the case of Jordan River in British Columbia, Canada – a watershed that is heavily influenced by resource extraction activities including mining, forestry and hydropower. BC Hydro finalized the Jordan River Water Use Plan (WUP) in 2003, which focuses on establishing critical freshwater flows for fish habitat and achieving specific recreational values of the local community (BC Hydro, 2003). However, numerous other issues still remain that were beyond the scope of the WUP process, including water quality concerns that were continually brought up by citizens during the consultative process of the WUP (BC Hydro, 2002). Currently, an inactive underground copper mine lies below the Jordan River, and high copper concentrations leaching from the mine are suggested to be responsible for the loss of the historic salmon runs in the Jordan River (BC Hydro, 2003; Wright & Guimond, 2003). Biological reports initiated by BC Hydro's Water Use Planning (WUP) process in the early 2000s indicate that contamination from the mine has affected and altered sensitive water quality parameters for a healthy Pacific salmon habitat in Jordan River (Burt, 2012). Yet, there has not been an extensive water quality study conducted that examines the spatial or seasonal water quality extents of the mining contamination in Jordan River, specifically copper.

Since resource extraction and land-use changes are projected to increase in British Columbia alongside climate change, it is expected that these changes will lead to altered freshwater availability, reservoir capacity, water quality and water use for future resource extraction and energy production (Simms & Brandes, 2016). Thus, Jordan River, provides an important case when reviewing the relationship between the state of freshwater quality in Canadian watersheds, and resource extraction operations in British Columbia. Lessons learned from this case may advance knowledge about resource extraction activities in a water quality context, applicable to watersheds heavily affected by resource development in British Columbia. In this research, I have addressed: *how have resource operations affected freshwater quality in the Jordan River watershed of British Columbia implicated in the WUP?*

# Methods

## Case Study Selection Criteria

A case study approach was chosen to address the research question. In order to select a well-suited case from the range of watersheds within BC and Canada, the following criteria were applied:

1. While a number of biological studies may have existed in a watershed, it was important that there have been limited water quality studies conducted to date that examine spatial and seasonal water quality trends of a variety of contamination parameters.
2. Diverse interests of the freshwater users and rights holders within the watershed are present, including multiple active resource industries (mining, forestry, and hydropower), First Nations, recreation, fisheries, and community; since the focus is specifically on watersheds dominated by resource development.
3. Existing and ongoing literature, information and studies will be accessible to provide some baseline knowledge of the watershed, even if research is needed about water quality.
4. The thesis research is valuable to the stakeholder groups and First Nations and may contribute to watershed decisions in the future.

## Case Study

The Jordan River watershed is located on the southwest coast of Vancouver Island approximately 72 kilometers from the provincial capital city of Victoria (Figure 5). The total area of the watershed is 165 square kilometers, and its hydrology is influenced mainly through precipitation and limited snowmelt that drains into the Juan de Fuca Strait (BC Hydro, 2003).

**Figure 5**

*The Jordan River Watershed*


*Note.* Reprinted from "Meeting Little Comfort for Jordan River Dam's Path" by A. Smart, 2014, *Times Colonist*. (https://www.timescolonist.com/news/local/meeting-little-comfort-for-jordan-river-residents-in-dam-s-path-1.1664167).

The Jordan River estuary was historically the traditional hunting and fishing territory of the Ditidaht and Pacheedaht First Nation. Pacheedaht settlements populated the mouth of the Jordan River, and were used seasonally to gather food for their community in Port Renfrew, B.C., approximately 40 kilometers north of the Jordan River. Resource extraction began in the Jordan River watershed in the early 1900s and resulted in the displacement of the Pacheedaht First Nation from their traditional hunting and fishing territory. Since then, the Pacheedaht have no longer been able to hunt, fish or harvest in the watershed due to effects of resource development, which led to the permanent decline of salmon and wildlife populations in the watershed. Today, a rural community of 150 non-Indigenous people lives within the watershed. Jordan River is located within a stretch of landscape dominated by provincial parks, coastline hiking trails, and campgrounds that attract high amounts of seasonal tourism. Year-round recreational users frequent the shores of Jordan River to pursue surfing and water sport opportunities. Historically, the Jordan River community was sustained by resource extraction operations within the watershed.

**Case Study Context**

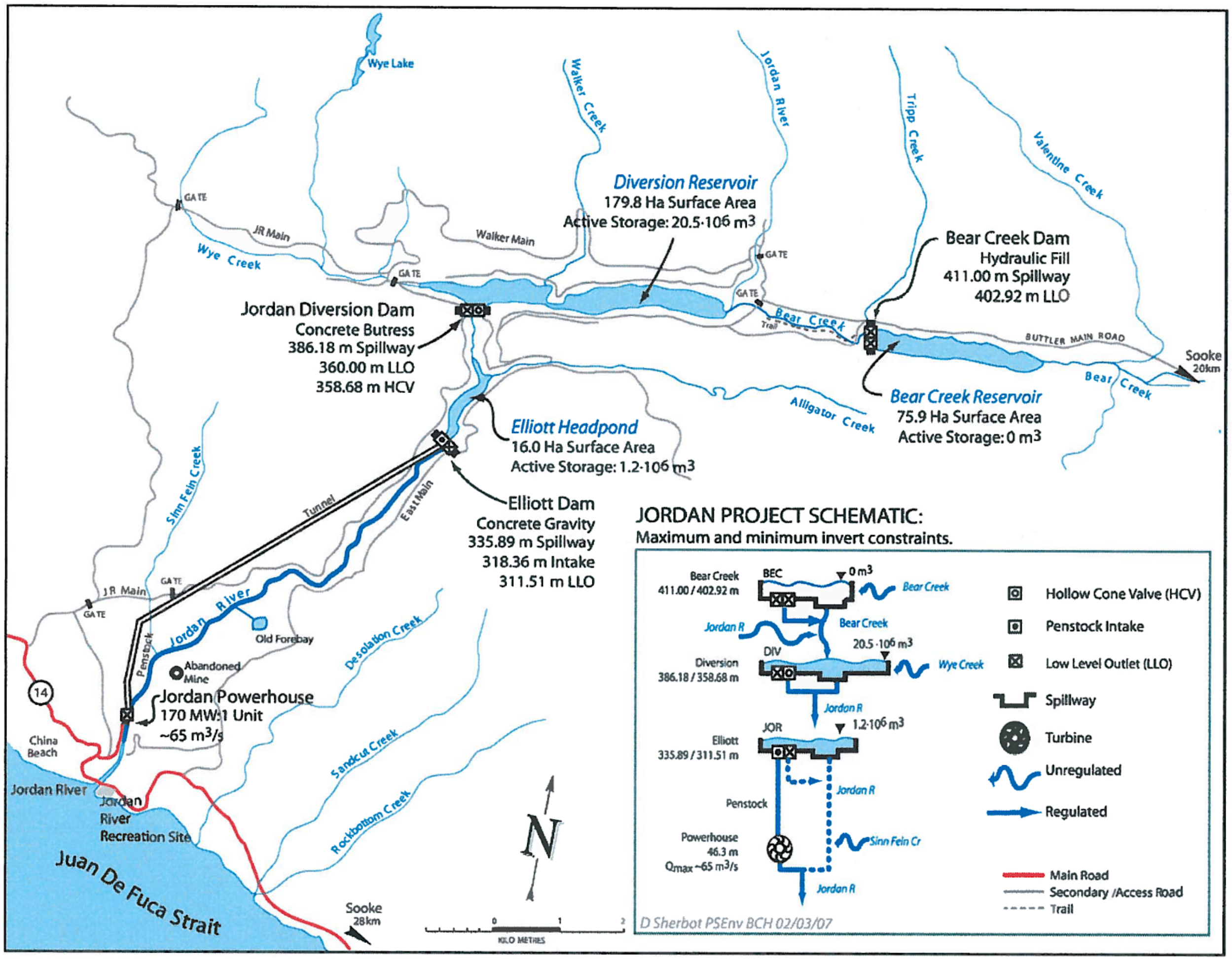
Hydroelectric development along Jordan River was initiated in 1909 and operated continuously from 1911 to 1971 (Wright & Guimond, 2003). In 1971, a 175 MW powerhouse was built to replace the original 26 MW powerhouse located on the east side of the Jordan River (Burt, 2012). The current powerhouse is part of a delivery system that has three hydropower dams, two reservoirs, a head pond, and a tunnel penstock delivery system in the Jordan River watershed (BC Hydro, 2003). The dams include Bear Creek Dam, which impounds Bear Creek Reservoir; Diversion Dam, which impounds Diversion Reservoir; and Elliot Dam, which impounds the Elliot Headpond (Figure 6). These generating facilities are part of BC Hydro's integrated generation system, and contribute to the only major hydroelectric development on the southwest coast of Vancouver Island (BC Hydro, 2003).

The hydroelectric development can generate up to 175 MW of power, and could potentially sustain approximately 35% of Vancouver Island's total electricity demands (BC Hydro, 2003). However, approximately 80% of the power demands of Vancouver Island are supplied by a submarine cable transmission system from the Lower Mainland (BC Hydro, 2003) and therefore, the current operating role of the Jordan River facility is defined as a "peaking plant" to meet voltage demands during peak times of the day, and offsetting the effects of transmission failures that may occur on the provincial transmission grid system (BC Hydro, 2003). Power generation, and thus the release of water from the storage facilities, generally occurs in the early mornings and afternoons to suit the peak demands of the population living on Vancouver Island, which unnaturally alters the flow in the Jordan River daily.

The BC Hydro facilities in the Jordan River watershed are operated according to the WUP, including the provisions addressing dam releases and fish flows. The Jordan River WUP process was initiated in April 2000 and completed in November 2001. The WUP Consultative Committee provided recommendations to the WUP regarding the hydro operations in the watershed (BC Hydro, 2003). The committee was comprised of fourteen members who expressed interests in First Nation cultural use and heritage sites, power, recreation, water quality, fish and wildlife, and socio-economic values of the watershed (BC Hydro, 2002). The Comptroller of Water Rights revised the Jordan River WUP in 2003 under the provincial *Water Act* (BC Hydro, 2003), which was superseded by the 2016 *Water Sustainability Act* (*WSA*) (Water Sustainability Act, 2014).

**Figure 6**

*BC Hydro Facilities in the Jordan River Watershed*




*Note.* Reprinted from *Jordan River Water Use Plan*, by BC Hydro, 2003.

An abandoned underground copper mine lies partially below the riverbed and can be accessed approximately 1.5 kilometers upstream from the coast on the east side bank. The workings of the mine are evident along the riverbanks, where the Jordan River flows directly through a portion of the mine. Copper mining began in the early 1900s and operated intermittently until 1977 when the main access tunnel of the mine collapsed. The mine was officially closed in 1993 by the Province of British Columbia. High copper concentrations are suggested to be responsible for the loss of the historic salmon runs in the Jordan River (BC Hydro, 2003; Wright & Guimond, 2003). Biological reports initiated as part of the WUP indicate that contamination from the mine has affected and altered sensitive water quality parameters for a healthy fish habitat in Jordan River (Burt, 2012). Yet, there has not been an extensive water quality study conducted that examines the spatial and seasonal water quality extents of the mining contamination, specifically copper. Recently, the copper mine has been purchased and is currently in the preliminary exploration stages of resuming operations (B. Olsen, personal communication, December 2, 2016).

The anadromous reaches of the Jordan River once supported runs of coho, chum and pink salmon (Hirst, 1991), as well as cutthroat and steelhead trout (Griffith, 1996). In 1958, chum salmon were no longer observed spawning in the Jordan River and by 1966 coho salmon escapements were non-existent (Burt, 2012). In 1972, the last of the Pacific salmon species, pink salmon, were no longer observed spawning in the Jordan River following the relocation of the powerhouse to the west side of the River in 1971 (Burt, 2012). Since the early 2000s, the T'Souke First Nations has been encouraging a re-establishment of salmon populations in Jordan River, under the incentive of re-initiating their fish and wildlife harvest rights that are outlined in the Douglas Treaty (BC Hydro, 2003; Hydro, 2016). The Pacheedaht First Nation has expressed cultural fishing, hunting and harvesting history with the Jordan River. These discussions have led to progressive collaboration efforts of the Jordan Watershed Round Table (JWRT) (refer to Chapter 3 of this thesis).

**Data Collection**

The following sections will discuss the data collection, including document review, water quality sampling, and analysis.

***Part I: Document Review***

In addition to collecting water quality data, select material was reviewed to collate all the information openly accessible about the WUP process in the Jordan River watershed, and any literature that may have provided background information on the Jordan River watershed relevant to the environmental state of the watershed, such as historic water quality contamination issues, ecological studies of salmon in the Jordan River watershed, physical geography and geology (including mineral exploration occurrence data and mineral exploration survey maps), industrial history of hydropower and mining, information on watershed-based habitat restoration projects and current watershed plans. Documentary information is almost always required for case study research (Yin, 2009). This was accomplished through academic search engines provided by the University of Victoria and open source key-word searches that recovered grey literature, scientific reports, media, management plans, consultative committee reports, provincial government documents, local meeting minutes and environmental assessment documentation of government agencies, funding programs, industry, environmental consultants, and community.

***Part II: Water Quality Sampling***

This study applied the British Columbia Approved Water Quality Guidelines (WQGs) specifically for freshwater aquatic life to assess water quality conditions in the Jordan River watershed.

**British Columbia Approved Water Quality Guidelines.** The British Columbia Approved WQGs are used to relate the physical, chemical or biological characteristics of water, biota or sediment to their effects on water use, including by aquatic life (Ministry of Environment, 2013b). The WQGs provide a basis for assessing water quality conditions in British Columbia, including defining safe levels of substances to protect different water uses, including drinking water, recreation, wildlife, agriculture and aquatic life (Ministry of Environment & Climate Change Strategy British Columbia, 2018). At the beginning of the data collection period of this research, British Columbia had WQGs for 40 substances, including the variables analyzed in this study: copper, aluminum, phosphorous, pH, dissolved organic carbon (DOC), hardness, turbidity, total suspended solids (TSS), water temperature, and sulphate ($SO_4$) (Ministry of Environment, 2013b). WQGs provide policy direction to staff making decisions affecting water quality, and do not have any legal standing, but must be considered in any decision affecting water quality in British Columbia (Ministry of Environment & Climate Change Strategy British Columbia, 2018). WQGs are reported as ambient guidelines, where average concentrations represent the natural background state of the watershed (Ministry of Environment & Climate Change Strategy British Columbia, 2018).

Using these guidelines, the water quality data collected in this study were compared against the WQG long-term average, where a minimum of five samples are needed to calculate the average over a specified averaging period, generally 5 samples in 30 days is the recommended sampling schedule for WQGs (Deniseger, McKean, & Chapman, 1995; Ministry of Environment & Climate Change Strategy British Columbia, 2018; Ministry of Environment, 2013b).

**Water Quality Sampling.** Water quality samples were collected over a five-week period from five specific sites on the Jordan River in September 2015 and concluded in October of 2015 (Figure 7). Water sampling was collected after a dry summer season in 2015, and within the first rain or major flow event indicating a Fall freshet to capture the seasonal concentrations in contaminated water flowing into the river from the mine site (Gray, 1997; C. A. Johnson & Thornton, 1987; D. B. Johnson & Hallberg, 2005). Sampling during the initial flow events also capture one of the most sensitive periods of salmon spawning activity in the lower reaches of the Jordan River (Burt, 2012). The toxicity of copper was examined by sampling the following physical, chemical and biological characteristics: total copper, dissolved copper, zinc, aluminum, phosphorous, pH, DOC, hardness, turbidity, TSS, water temperature, and sulphate ($SO_4$). The water samples were analyzed at an accredited laboratory using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), which can detect a variety of metal and non-metal concentrations.

**Figure 7**

*Jordan River Study Sites and Extent of Copper Mine Main Access Tunnel*


*Note.* Adapted from *Google Earth* (https://www.google.com/earth/).

Site 1 (48°28'33.00"N 123°59'56.00"W) was selected as the control site to capture the natural background state of the water quality in the Jordan River because the location is above any influence from the copper mine and below Elliot Dam. Site 2 (48°27'2.60"N 124° 1'55.30"W) and Site 3 (48°26'58.50"N 124° 2'3.40"W) were selected based on their locations which are within the 2.6-kilometer extent of the copper mine main access tunnel along the Jordan River. Site 4 (48°25'48.20"N, 124° 3'5.00"W) was selected from a location downstream of the copper mine, and waste rock pile. Site 4 is located above the tailrace of the BC Hydro powerhouse, which could inconsistently dilute the concentrations experienced by the freshwater aquatic life downstream. Site 4 is also located just above the tidal influence at the mouth of the River to ensure freshwater sampling with no marine influence. Site 4 is also the historic freshwater spawning area for salmon in the Jordan River. Areas of acidity in the River would most likely support evidence of acid mine drainage (AMD), and demonstrate the highest amount of copper in the surface water (Barry, Grout, Levings, Nidle, & Piercey, 2000; Deniseger et al., 1995; Gray, 1997). Therefore, a pH meter was used to locate areas of high acidity and led to the decision to sample an off-channel seep that flows through a waste rock and tailings pile below an abandoned mine portal and into the main channel of the Jordan River. The seep was selected as Site 5 (48°25'57.20"N 124° 3'7.90"W), along with the observation of significant precipitate and staining.

Additional site observations were recorded on a field card including site ID, GPS coordinates, water color, temperature, pH, date, time, recorder, geology, weather, and any other observations (refer to Appendix 1: Jordan River Field Card). The water samples from all five sites were collected within 48 hours on a weekly basis (refer to Appendix 2: Water Quality Sampling Schedule and Results) using one-liter Nalgene water bottles supplied by the laboratory. Additional care was taken to not introduce any cross-contamination in the sampling process by using latex gloves, rinsing the bottles at the sample site before collection, and not reusing sampling supplies. The water samples were immediately placed in a cooler to sustain water chemistry and transported within 24 hours to MB Labs in Sidney, British Columbia. A quality control program was used in the sampling design to test the accuracy of the laboratory methods and minimize experimental, field and instrumental error. The quality control program included one blank sample of deionized water, one known concentration of copper standard, and duplicate samples in each weekly batch of water samples collected (Ministry of Environment, 2013a). Site photos were taken of the samples at the site with the field card clearly displaying Site ID number, in addition to upstream, downstream and any notable physical observations at the site (e.g. precipitation, algae, or rock staining).

**Water Quality Analysis.** A total of 40 water quality samples, including quality control samples of blanks, standards and duplicates were taken from the five sites in the Jordan River. Each site on the Jordan River had been sampled five times and concentrations were averaged to represent a 30-day average concentration that could be compared against the British Columbia Approved WQGs specific to the variables sampled. The 30-day average concentrations for total copper, dissolved copper, zinc, aluminum, phosphorous, pH, DOC, hardness, turbidity, TSS, water temperature, and sulphate ($SO_4$) were reviewed and summarized in excel tables. The duplicate concentrations of the quality control program were averaged, and any concentrations below detection levels were recorded as the median of the detection limit in the analysis. The 30-day average concentrations were used to generate bar and line graphs and whisker box plots using Microsoft Excel to portray patterns and anomalies in relation to WQGs at specific sites. Historical climate data from Environment Canada, such as monthly precipitation data from a nearby weather station, Sheringham Point, was incorporated in the analysis.

## Results

This section describes key themes and findings of the document review and analysis of water quality samples.

### Part I: Document Review

The document review provided background information on the Jordan River watershed relevant to the environmental state of the watershed, such as historic water quality contamination issues, ecological studies of salmon in the Jordan River watershed, industrial history of hydropower and mining, information on watershed-based habitat restoration projects and current watershed plans.

#### ***Hydro Operation under the Water Use Plan***

The proposed operating conditions in the WUP were expected to improve and increase the quality of fish habitat for resident fish populations downstream in lower Jordan River (BC Hydro, 2003). BC Hydro aimed to commit to a greater base flow that would increase salmonid success in the lower Jordan River by improving water temperature and water quality in the summer months (BC Hydro, 2003). In 2008, BC Hydro installed a fish water release pipe at the Elliot Dam, and an agreement was made through the Jordan River WUP to maintain a year-round base flow release of 0.25 cubic meters per second (Burt, 2012). Due to concerns of the release valve malfunctioning and potentially destroying downstream fish habitat, a decision was made to keep the valve of the release pipe in a locked open position, which resulted in a flow release of about 0.30 to 0.40 cubic meters per second from the Elliot Headpond (Burt, 2012). Prior to 2008, there was no guaranteed base flow in the Jordan River, except when the dam was spilling during a flood event, which resulted in the downstream fish habitats being dependent on tributary inputs (Burt, 2012). Flows in the Jordan River were as low as 10 – 12 litres per second (0.010 to 0.012 cubic meters per second) during the dry summer months (Burt & Hudson 2008, 2009). The lack of freshwater flows in the Jordan River heavily impacted downstream fish habitat.

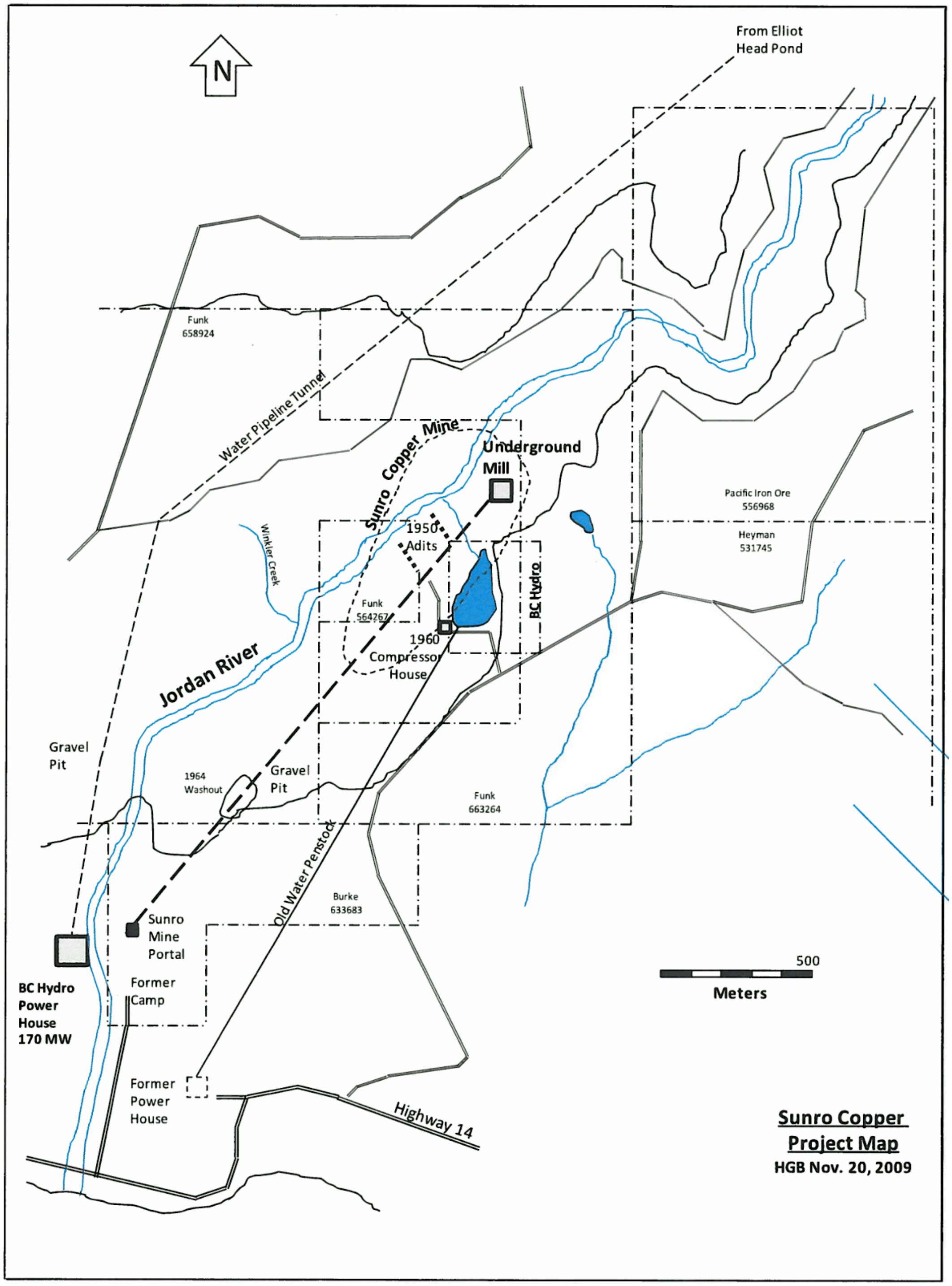
The WUP outlined uncertainties and information gaps in the proposed operating procedures, and recommended that the Comptroller of Water Rights direct BC Hydro to implement a monitoring program that would reduce these uncertainties over time by assessing the outcomes of the operational changes and providing additional information that can be used to inform future operating decisions (BC Hydro, 2003). These uncertainties included a lack of information on establishing minimum base flows to increase downstream ecological habitats, specifically influencing river-bearing rainbow trout; metal toxicity and critical low flows that may impact the success and survival of spawning and rearing salmonid species; response level to stress of reservoir rainbow trout associated with draw downs, and whether or not discharge reduction enhances surf quality on select weekends in March (BC Hydro, 2003). As a result, a number of projects have been conducted in the watershed since 2003 that focus on monitoring the uncertainties outlined in the WUP (Burt, 2006, 2007, 2008, 2009, 2010, 2011, 2012; Cascadia Biological Services, 2006, 2007, 2009, 2010a, 2010b, 2011). A review of the Jordan River WUP is recommended to occur every six years (BC Hydro, 2003), but it was not until 2014 BC Hydro announced that the provincial review of all the WUPs in the province is to commence January 2015 and conclude in 2030 (BC Hydro, 2015). However, a WUP review can be triggered at any time by the Comptroller of Water Rights if scientific information or new risks are identified that could result in a change of operations (BC Hydro, 2003).

### ***Historical Mining Development***

Copper mining began in the watershed in 1919 and operated intermittently following the price of copper until 1977 when the main access tunnel of the mine collapsed. At full production, the mine was generating 1,900 tonnes of copper concentrate from 173,000 tonnes of mined and milled ore annually (Burke, 2012b). The main access tunnel was completed in 1956, and extends 2.6 km along the Jordan River allowing access to a number of ore bodies resulting in an extensive network of underground tunnels (Burke, 2012a) (Figure 8 & 9). A unique feature of the Jordan River copper mine was the presence of an underground mill room (Funk & Burke, 2011). High grade ore was crushed and milled copper concentrate and hauled from the mill room through the main access tunnel by rail cars, and transferred into trucks at the mine portal to be off loaded in Cowichan Bay, B.C. (Burke, 2012b).

**Figure 8**

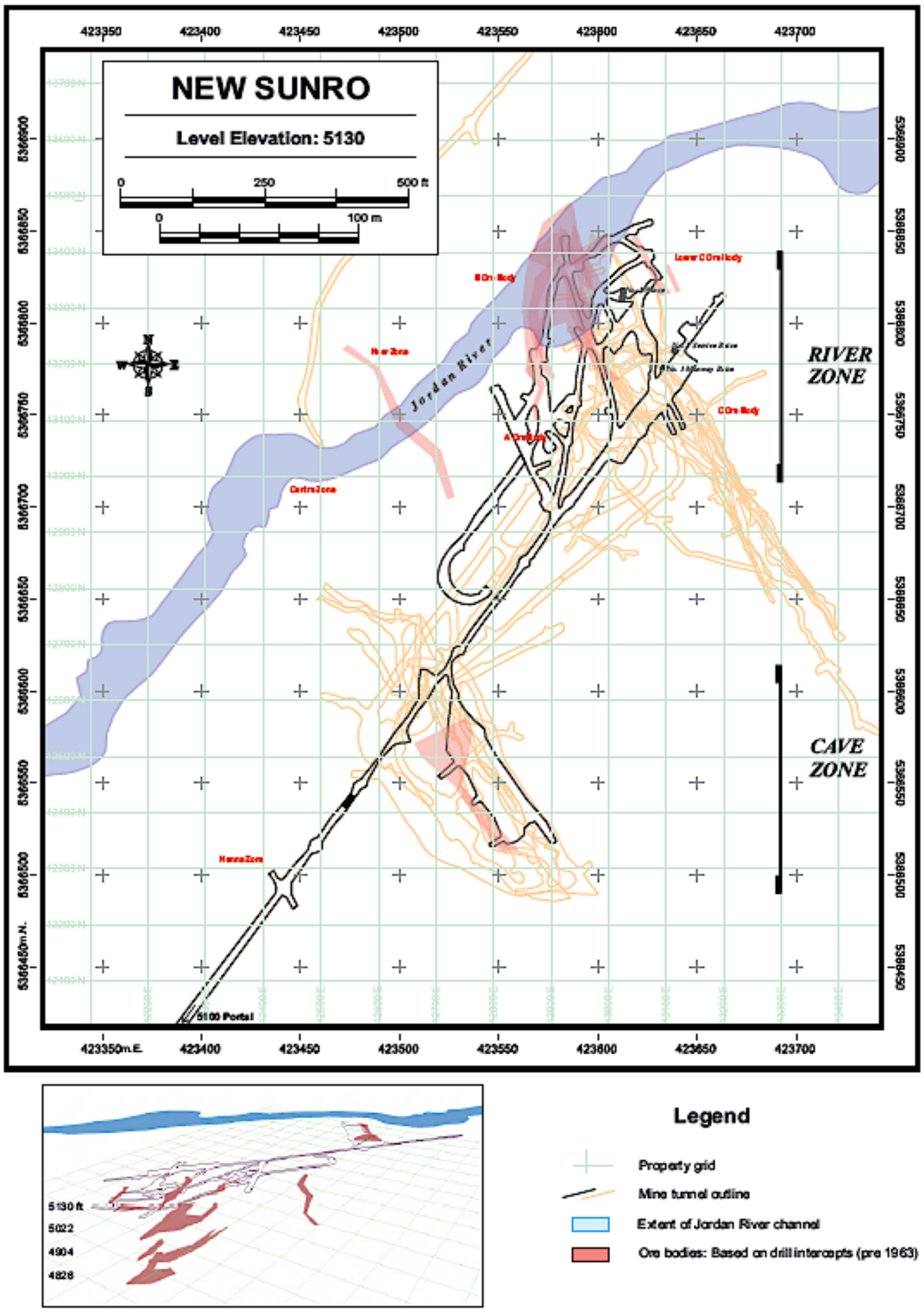
*Map of Jordan River Copper Mine*




*Note.* Reprinted from *Sunro Copper Mine Restart Project: Jordan River, British Columbia, Canada*, by K. Funk and H. Burke, 2011.

**Figure 9**

*Map of Mine Tunnels and Copper Ore Bodies in the Jordan River Watershed*




*Note.* Map created by Wayne Jackaman, of Noble Explorations Services Ltd., 2015.

A 15-centimeter wide submarine tailings pipe was constructed in 1961, and still exists today along the eastward side of the River (Figure 8). The submarine tailings pipe extends one kilometer offshore, and discharges at a shallow depth of 12 meters (Ellis, 2008). Literature suggests that the tailing pipe broke several times, and aerial photographs taken during the operation of the mine show a plume of tailings rising to the surface (Ellis, 2008).

A study conducted in 1991 found that the tailings pipe was slowly discharging residual contaminates into the shallow ocean waters at the mouth of the River, which have accumulated into a man-made metal deposit south of the Jordan River along parklands following long-shore drift currents (Kilby, 1991, 1994). A total of 1.3 million metric tonnes of waste rock and tailings were generated from the production of the mine and 95% was deposited into the ocean at the mouth of Jordan River (Burke, 2012b). The other 5% of tailings and waste rock were deposited along the banks of the Jordan River, and the majority still remain today in the form of large piles on the eastside of the River approximately one kilometer upstream from the mouth of the river.

A portion of this contaminated material was sourced from a catastrophic event that occurred at the mine in 1964. Copper was being extracted from an ore body that was located directly below the River in an area of the mine called the River Zone (Figure 9). Heavy rainfalls transpired into a flood event for the Jordan River, and caused the roof of the stope to collapse. The Jordan River flowed into the mine, and water flooded the mill room, and travelled down the access tunnel. Pressure began to build as river debris plugged the access tunnel, and the water burst out onto a ridge above the mine ejecting machinery, concentrate, waste rock, tailings, tools, and debris from the mine into the Jordan River (Victoria Daily Times, 1964). An estimated 76, 460 cubic meters of gravel, silt and debris washed into the Jordan River (Victoria Daily Times, 1964). A new channel was formed below the mine portal from the ridge that was filled with 4 feet of gravel and debris into the Jordan River (SNC Lavalin, 2016). Some of the water rushed out of the main access tunnel through the mine portal and washed away a railway trestle into the river. The river was choked full of debris, sediments, tailings, copper concentrate from the underground mill room, machinery and waste rock. This event halted log booming operations at the mouth of Jordan River for three years, and logs had to be trucked to Sooke. During that time the river was dredged, and the material was used to fill in a large salt marsh in the estuary of the Jordan River. The salt marsh became the site of the log sort that is still present today at the mouth of the river (Capital Regional District, 2014). The mine resumed production operations until 1977 when the main access tunnel collapsed (Burt, 2012; SNC Lavalin, 2016). In 1993, the Ministry officially closed down the mine following an installment of a 34-meter rock plug in the tunnel outside the mill room (Burt, 2012).

***Cumulative Impacts on Salmon Habitat***

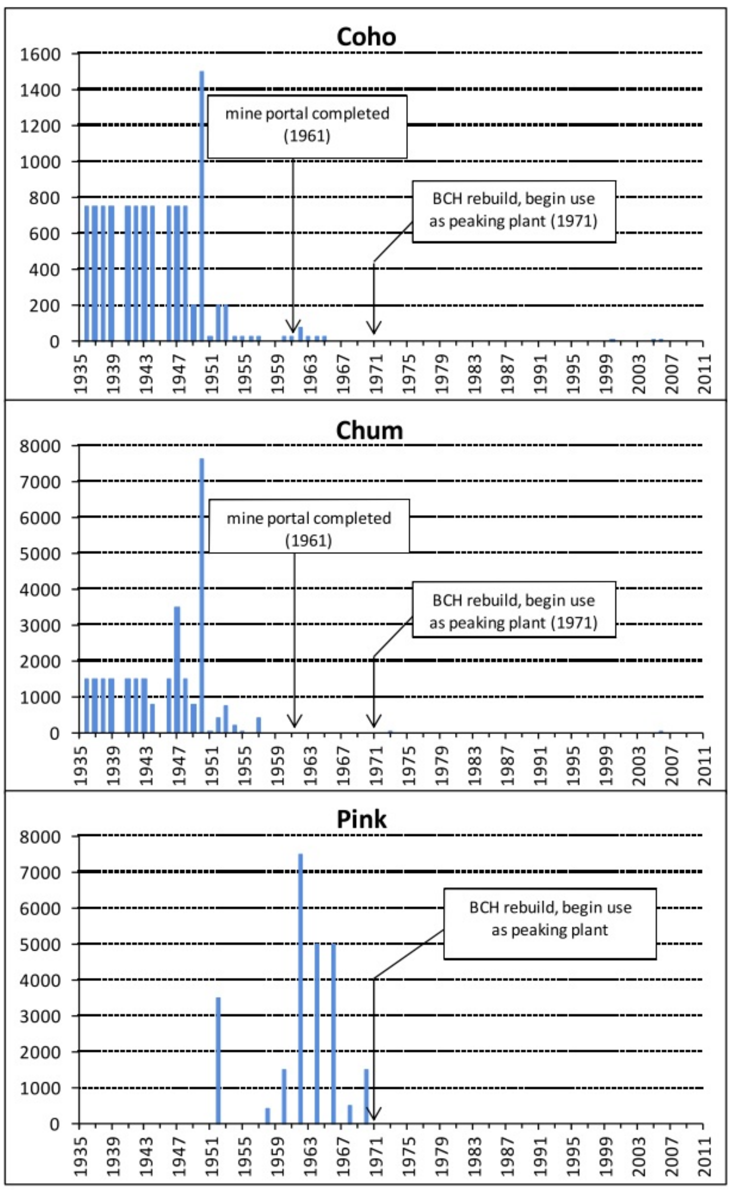
In British Columbia, Pacific Salmon are considered to be extinct in 142 watersheds throughout the province (T. L. Slaney, Hyatt, Northcote, & Fielden, 1996) and have disappeared from 40% of their historic spawning range in the Pacific Northwest due to habitat loss (Gresh, Lichatowich, & Schoonmaker, 2000; National Research Council, 1996; Nehlsen, Williams, & Lichatowich, 1991). The Jordan River watershed once hosted native salmon runs of coho, pink, and chum that no longer exist due to the cumulative effects of multiple resource extraction activities and BC Hydro energy facilities that are present within the watershed (Wright & Guimond, 2003). The presence of these salmon runs held significant cultural importance to the Pacheedaht, T'Souke and Ditidaht First Nations (BC Hydro, 2003). Resource extraction practices, such as forestry and mining, have been present in the watershed since the late 1800s. Forestry operations began in 1880 and are currently active in the lands surrounding the watershed today (Wright & Guimond, 2003). A dry land sort and log booming operation exists at the mouth of the Jordan River. Over the last few decades, research suggests that copper contaminants from the mine have been continuously leaching into the river and have contributed to the loss of aquatic life in the lower reaches of the Jordan River (Wright & Guimond, 2003). Overall, it is clear that the cumulative effects of the copper contamination, and resource extraction activities from hydropower and forestry have led to detrimental impacts on fish habitat in the Jordan River.

The anadromous reaches of the Jordan River once supported runs of coho, chum and pink salmon (Hirst, 1991) (Figure 10), as well as cutthroat and steelhead trout (Griffith, 1996). In 1958, two years after the excavation of the main access tunnel was completed at the mine, chum salmon were no longer observed spawning in the Jordan River (Burt, 2012). By 1966 coho salmon escapements were non-existent (Burt, 2012). In 1972, the last of the Pacific salmon species, pink salmon, were no longer observed spawning in the Jordan River following the relocation of the powerhouse to the west side of the River in 1971 (Burt, 2012). Since the early 2000s, the T'Souke First Nation have been encouraging a re-establishment of salmon populations in Jordan River, under the incentive of re-initiating their fish and wildlife harvest rights that are outlined in the Douglas Treaty (BC Hydro, 2003; Hydro, 2016). The Pacheedaht First Nation claims that the Jordan River was once a fundamental place to harvest salmon for their livelihood pre-industrial development. The first documented escapement records are from 1936, and indicate an annual spawning estimate of 750 coho and 1500 chum (Burt, 2012). The loss of coho and chum salmon habitat may be due to the deposition of tailings into the river during mining operations, loss of rearing habitat when the salt marsh was filled in the estuary as a log sort, or the inconsistent flow releases from the BC Hydro dams (Burt, 2012).

Pink salmon returns reported a mean escapement of 3000 fish, where this species heavily relied on the consistent freshwater flows from the 500-meter tailrace of the original BC Hydro powerhouse (Hirst, 1991). When the original BC Hydro powerhouse was decommissioned in 1971 and moved to the west side of the river as a peaking plant, the pink salmon no longer spawned. The new BC Hydro powerhouse currently operates as a peaking plant today, with inconsistent flows and radical fluctuations from 0 to 67 cubic meters per second in short time intervals (Burt, 2012). The inconsistent high energy flows from the peaking plant strand juvenile and adult salmon when the flows drop, which make the fish very susceptible to predation from birds, wildlife, and marine mammals. The increased flows displace the juveniles downstream and disrupt the spawning of adult salmon by scouring and washing away any available spawning gravel into the ocean (Burt, 2012).

**Figure 10**

*Escapement Records for Coho, Chum and Pinks in the Jordan River*




*Note.* Reprinted from *Summary of Water Quality and Biological Data for Anadromous Reaches of the*

*Jordan River*, by Burt, 2012.

### ***Future Water Quality Efforts***

The Jordan River community is in the process of creating a community watershed management board (Hydro, 2016), similar to the Cowichan Watershed Board (Hunter, Brandes, & Moore, 2014), and Shawnigan Residents Association. The Fish and Wildlife Compensation Program (FWCP) has granted funding to the Pacheedaht First Nation to create a watershed plan, and are currently assembling the JWRT, which will include agency representatives, First Nations, local landowners, and other interested parties for the purpose of overseeing efforts on the river to restore salmon habitat (Hydro, 2016) (refer to Chapter 3 of this thesis). As a result of their growing concerns for water quality in the Jordan River, the community wants to have more authority over decisions in their watershed.

## **Part II: Water Quality**

The 30-day average concentrations for hardness, pH, temperature, TSS, turbidity, total copper, dissolved copper, DOC, zinc, aluminum, phosphorous, and sulphate ($SO_4$) were used to generate tables, graphs and plots to portray patterns and anomalies in relation to WQGs at specific sites.

### ***Average Hardness, pH, Temperature, TSS, and Turbidity***

The 30-day average hardness, pH, temperature, TSS, and turbidity results were below or within BC WQGs on all sites of the Jordan River during the period of the water quality study. Table 3 summarizes the average hardness, pH, temperature, TSS, and turbidity data in relation to the WQGs for freshwater aquatic life.

**Table 3**

*Summary of 30-day Average General Water Quality Parameters in the Jordan River*

| Water quality parameter | Site 1: Control (Elliot Dam) | Site 2: Mine 1 | Site 3: Mine 2 | Site 4: Above powerhouse | Site 5: Waste rock & portal seep | BC WQG |
|---|---|---|---|---|---|---|
| **Average Hardness (mg/L)** | 5.5 | 5.5 | 6.1 | 7.2 | 33.5 | **< 50.0 mg/L for soft water** |
| **Average Field pH** | 7.2 | 7.5 | 7.3 | 7.7 | 7.8 | **6.5 - 9.0** |
| **Average Temp (C)** | 13.5 | 13.2 | 13.3 | 13.5 | 10.3 | **4.4 -12.8 (± 1 C change beyond optimum temperature range)** |
| **Average TSS (mg/L)** | 0.8 | 0.6 | 0.7 | 1.0 | 1.3 | **Exceedance of 25 mg/L in 24 hrs OR 2 NTU in 30 days** |
| **Average Turbidity (NTU)** | 0.9 | 0.6 | 0.5 | 0.5 | 1.1 | **Exceedance of 8 NTU in 24 hrs OR 2 NTU in 30 days** |

The surface water of Jordan River is categorized as soft, with an average hardness at all the sites below 50 mg/L. The hardness varied throughout the sites downstream, and was recorded the highest, 33.5 mg/L, at Site 5 in the waste rock and portal seep due to the exposed highly mineralized rock. The pH of Jordan River is slightly alkaline, increasing in alkalinity, 7.2 to 7.7, downstream from Site 1 through Site 4. The waste rock and portal seep at Site 5 displayed the highest alkalinity with an average pH of 7.8. The alkalinity of the water may be due to the underlying bedrock geology and carbonate parent materials of the river system, or the addition of sulphate through AMD chemical processes (Meays & Nordin, 2013) which were slightly evident at Site 5. The overall average temperature of the Jordan River was approximately 13.4 degrees Celsius, where the waste rock and portal seep at Site 5 was slightly cooler at 10.3 degrees Celsius. The temperatures recorded throughout the study were within the ± 1 degree Celsius change beyond optimum temperature range (4.4 degrees Celsius to 12.8 degrees Celsius) for the most known sensitive salmonid species present in the Jordan River (coho, pink and chum) during the spawning life cycle (Ministry of Environment & Climate Change Strategy British Columbia, 2018).

The 30-day average turbidity was recorded well below WQGs at all sites during the study period (Table 3). Turbid waters can indirectly and directly inhibit fish productivity and community structure, some examples include: clogging or abrading gills, affecting migration patterns, blanketing of spawning gravels, disabling egg and fry development and reducing feeding regimes (Singleton, 1985). Previous research has suggested that changes to turbidity to levels to as low as 25 NTU, can cause a reduction in fish growth (Caux, Moore, & MacDonald, 1997), although this was not evident in the values recorded in the Jordan River. Turbidity increases during clear flows from background levels by 8 NTU in 24 hours at any one time, or 2 NTU in 30 days at any one time are considered an exceedance of the recommended ambient water quality criteria for aquatic life in British Columbia (Caux et al., 1997). This trend was not observed in the duration of the study in the Jordan River due to the time frame and seasonal constraints, and more research would be recommended to explore long-term turbidity trends.

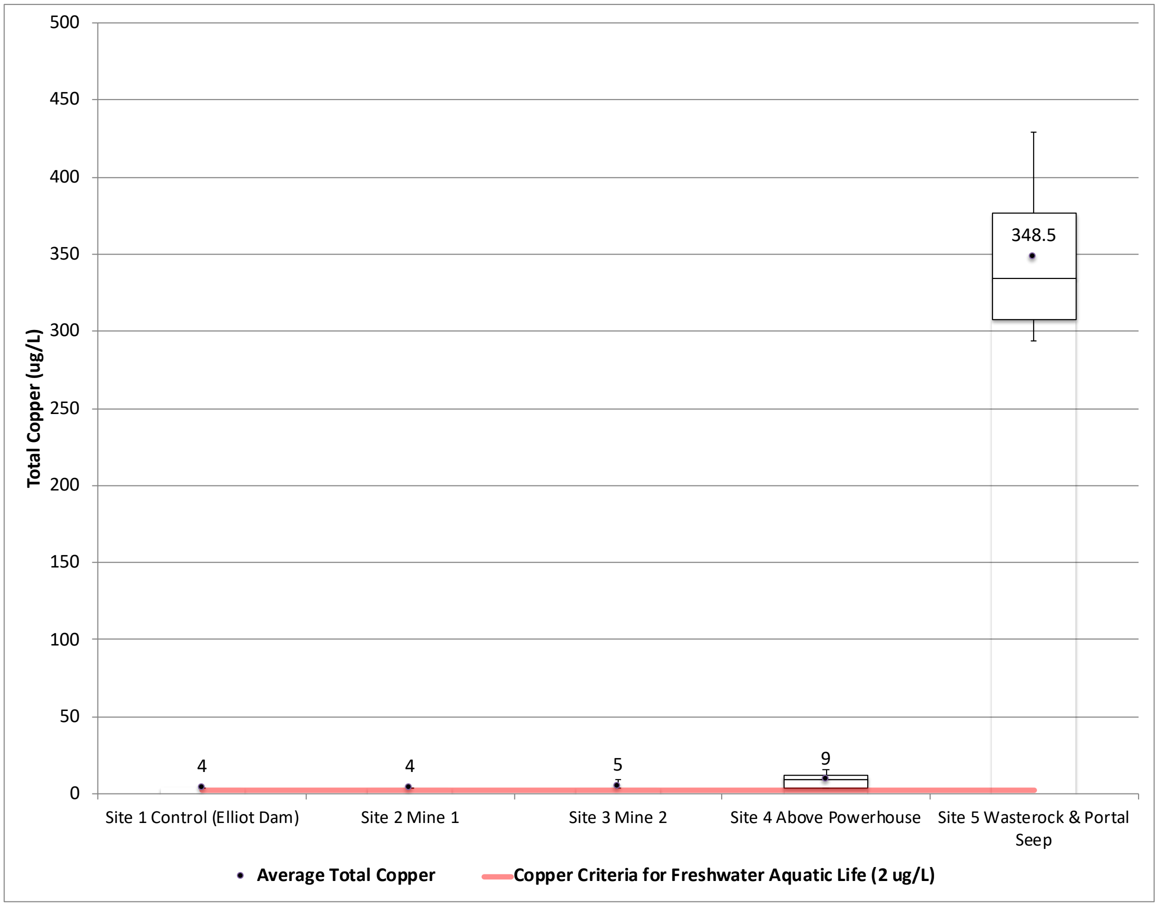
The 30-day average TSS was recorded well below WQGs at all sites during the study period (Table 3). Fish are the most sensitive aquatic organism to suspended sediments in their environments at all stages of their life cycle (Caux et al., 1997). Concentrations of suspended sediments as low as 7 mg/L are enough to produce a mortality rate of 40% on rainbow trout eggs, as the settled sediments can disrupt gas exchange and metabolic wastes between the egg and water with even just a few millimeters of covering (P. A. Slaney, Halsey, & Smith, 1977). Suspended sediments between 100 mg/L and 1000 mg/L are known to inhibit fish growth (Caux et al., 1997), and higher than 1500 mg/L can create anoxic environments for salmon (Servizi & Martens, 1987). In British Columbia, the adult sockeye salmon of the Fraser River are threatened by sediment load during their spawning season (Servizi & Martens, 1987). Suspended sediment changes that increase during clear flows from background levels by 25 mg/L in 24 hours at any one time, or 5 mg/L in 30 days at any one time are considered an exceedance of the recommended ambient water quality criteria for aquatic life in British Columbia (Caux et al., 1997). More research would be recommended on the Jordan River to evaluate whether or not turbidity or TSS are exceeded on the Jordan River at one time, but for the duration of this study no exceedance was detected.

***Total Copper***

Total copper is useful in determining toxicity in surface waters because it provides a measurement that includes all the copper that may potentially be toxic, and there is a considerable amount of historical background data that exists in the province using total copper (Singleton, 1987). In British Columbia the ambient water quality criteria uses total copper to determine toxicity (Singleton, 1987). The 30-day average total copper provincial limit for freshwater aquatic life is 2 ug/L, where average hardness is less than or equal to 50 mg/L (Singleton, 1987). The criteria for copper vary according to the hardness of the water, where alkalinity and pH govern the formation of copper complexes, and dictate site specific toxicity thresholds (Ministry of Environment, 1987). Soft water with a concentration of calcium carbonate ($CaCO_3$) below 50 mg/L will have a lower threshold value for copper (less than or equal to 2 ug/L), than hard water (above 50 mg/L of CaCo3) which can increase the toxicity threshold for freshwater aquatic life (less than or equal to 0.04 ug/L multiplied by average hardness) (Ministry of Environment, 1987). Generally, increasing water hardness increases the tolerance of freshwater aquatic life to copper (Spear & Pierce, 1979). The average hardness in Jordan River was below 50 mg/L, for the duration of the sampling period, therefore the copper criteria is less than or equal to 2 ug/L. The 30-day average total copper results for the Jordan River are presented in Figure 11.

**Figure 11**

*30-day Average Total Copper for the Jordan River*



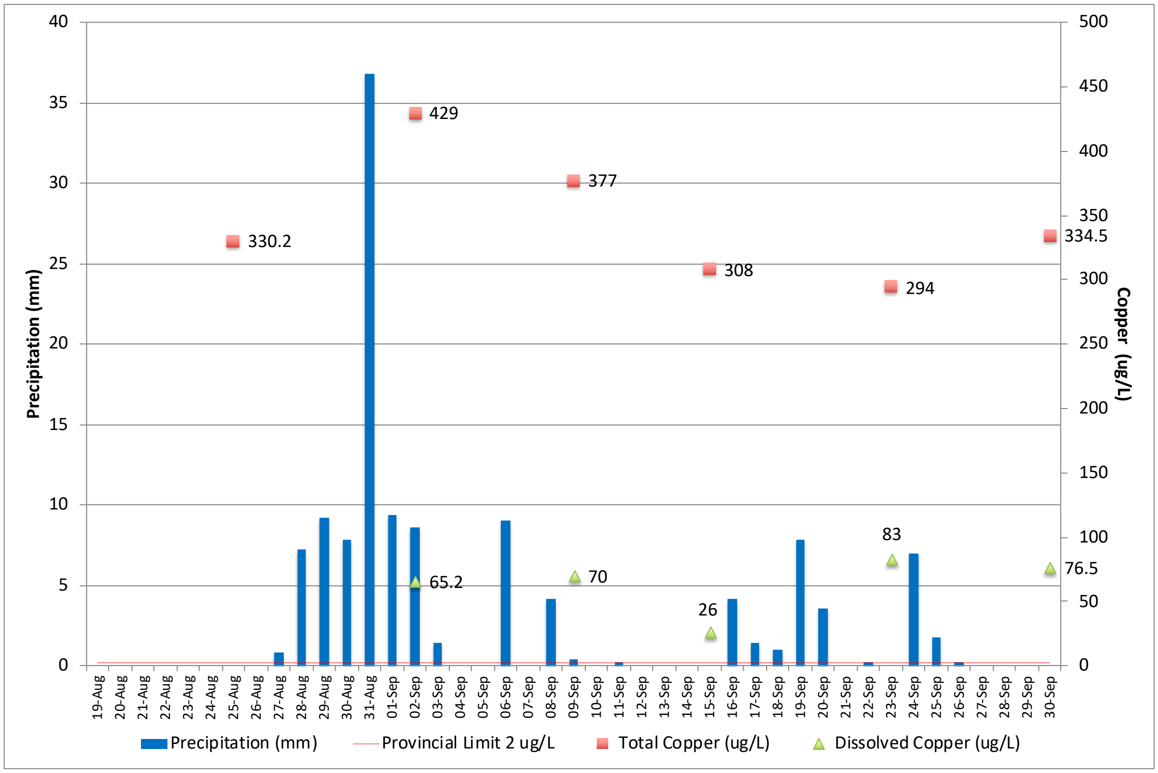

*Note.* Average total copper over five weekly samples within a 30-day period through September and August 2015, using the Ministry of Environment Ambient Water Quality Criteria. The box plots display the interquartile range of the data, including median, mean, $75^{th}$ and $25^{th}$ percentiles (upper and lower respectively). The whiskers display the range of minimum and maximum recorded values.

The natural background total copper levels at control Site 1, were 2 times the provincial limit for copper at 4 ug/L, which reflects the naturally occurring content of copper in igneous and metamorphic bedrock present in the Jordan River watershed. Sites 2 and 3, were 4 ug/L and 5 ug/L respectively. The river channel below the mine portal and waste rock pile at Site 4 had elevated 30-day average total copper levels of 9 ug/L. The copper concentration incrementally increased downstream as it flowed past the mine. The highest 30-day average total copper concentration was recorded at Site 5, which was located in a seep that flows below the main mine portal through a waste rock and tailings pile into the main channel of Jordan River. Surface waters in the seep reached a 30-day average of 348.5 ug/L, which was 174.3 times above the provincial limit for freshwater aquatic life. The 30-day average total copper at Site 5 (348.5 ug/L) exceeds the maximum total copper provincial limit for wildlife (300 ug/L) and irrigation (200 ug/L) but was below the maximum limit for drinking water (500 ug/L). High copper levels inhibit the ability of aquatic life to forage food, and is known to affect their olfactory mechanisms (Singleton, 1987).

The water quality samples were taken over a five-week period during a very dry summer and drought year in 2015. The sampling period of the study was designed to capture the effects of the first rains of a Fall freshet event after the dry summer months. Previous scholarship has found that metal concentrations, such as copper, are influenced by rainfall events and high concentrations of these metals would be easily detected in the runoff from the mine site (C. A. Johnson & Thornton, 1987; D. B. Johnson & Hallberg, 2005; Singleton, 1987). The study captured the initial rainfall of a Fall freshet after a dry summer season in 2015 and revealed a strong positive relationship between copper concentrations and precipitation data from a nearby weather station at Site 5 (Figure 12).

**Figure 12**

*Total and Dissolved Copper Concentrations Response to Precipitation at Site 5*




*Note.* Water sampling period August through September 2015.

*Environment Canada - Historical Climate Data: Daily Precipitation at Sheringham Point, British Columbia (43°22'36.10"N, 123°55'15.700" W), August and September 2015 (https://climate.weather.gc.ca/climate_data/daily_data_e.html). In the public domain.

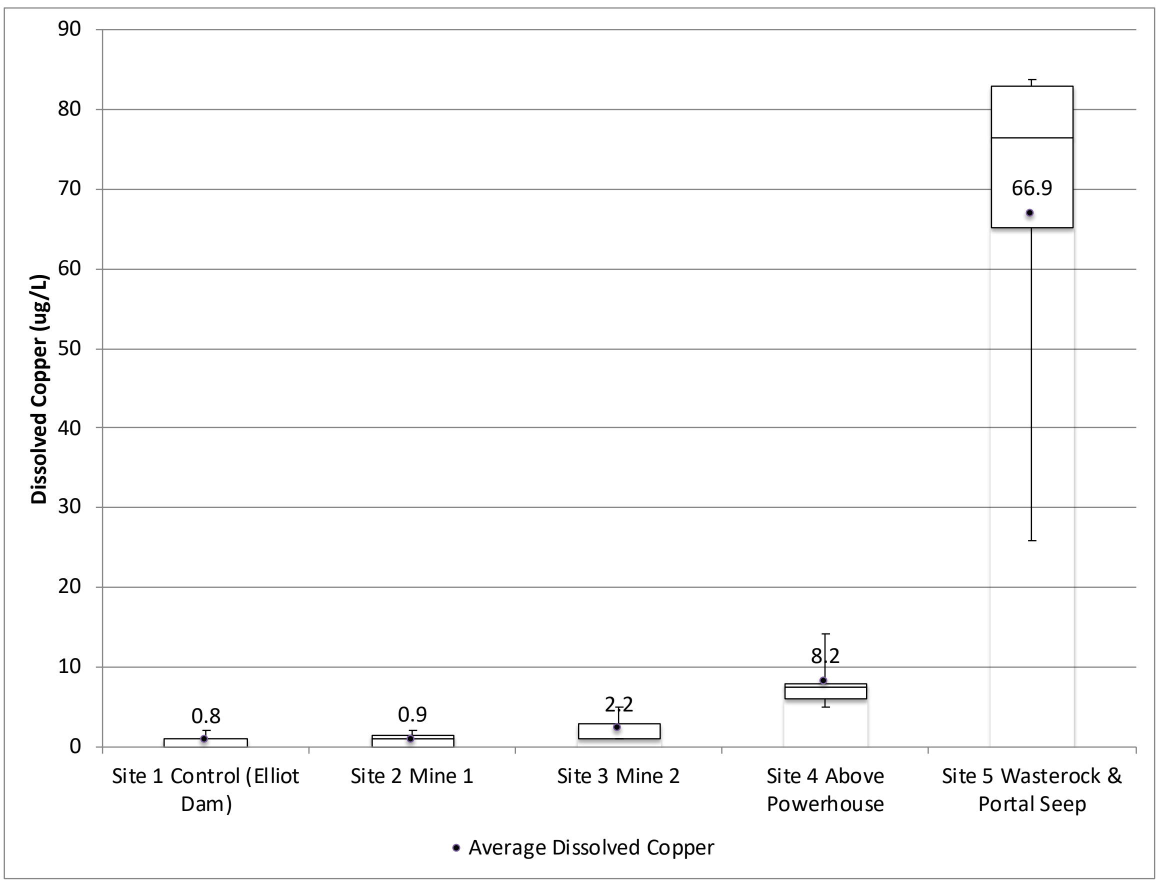
On September 2nd, 2015, the copper concentrations at Site 5 in the waste rock seep spiked to 429 ug/L following 36.8 mm of precipitation on August 31, 2015. The rainfall event on August 31st was the greatest during the five-week sampling period, where overall rainfall was 0 or below 10 mm throughout the study. The copper concentrations in the following weeks corresponded to the decrease in rainfall, which was below 10 mm, and the copper returned to concentrations prior to the initial rainfall event approximately 294 ug/L-330 ug/L at Site 5.

***Dissolved Copper***

Dissolved copper is a measurement of the bioavailable copper, which is the most soluble form of copper that can absorbed or metabolized by freshwater aquatic life causing toxicity (Singleton, 1987). Dissolved copper is a measurement that does not include particulate or total copper. It is a useful parameter in water quality studies, because it can provide a relative understanding of toxicity when comparing between different sites (Singleton, 1987). The results of the 30-day average dissolved copper for the Jordan River are presented in Figure 13.

**Figure 13**

*30-day Average Dissolved Copper for the Jordan River*



*Note.* Average dissolved copper over five weekly samples within a 30-day period through September and August 2015, using the Ministry of Environment Ambient Water Quality Criteria. The box plots display the interquartile range of the data, including median, mean, 75$^{th}$ and 25$^{th}$ percentiles (upper and lower respectively). The whiskers display the range of minimum and maximum recorded values.

The dissolved copper in the Jordan River increased from the control Site 1 downstream as it reached the vicinity of the mine site, from levels of 0.8 ug/L to 8.2 ug/L. The waste rock seep 30-day average dissolved copper values were the highest of all the sites sampled in the Jordan River at 66.9 ug/L, which mirrors the trend of the total copper concentrations. Typically, surface waters in Canada rarely exceed dissolved copper levels over 5 ug/L (Singleton, 1987; Spear & Pierce, 1979). The dissolved copper levels in Jordan River exceeded 5 ug/L at Site 4 and 5 downstream from the mine at a 30-day average of 9 ug/L and 66.9 ug/L respectively. Sites 1, 2, and 3 were below the acceptable threshold defined by Ministry of Environment of 5 ug/L.

***Dissolved Organic Carbon (DOC) and Binding Metals***

DOC plays a central role in balancing aquatic chemistry as it can combine with other metals and nutrients, and buffer toxicity to aquatic life (D. R. J. Moore, 1998). DOC tends to bind with cadmium, aluminum, silver, zinc and copper to create stable organic compounds, and in doing so, reduces the toxicity of these metals to aquatic life (D. R. J. Moore, 1998). DOC can also bind with phosphorous, creating iron-phosphate complexes (D. R. J. Moore, 1998), and reduce the bioavailability of phosphorus, which can influence the risk of anoxic environments and altered aquatic plant and animal biodiversity in a system (Chambers et al. 2001, Ministry of Environment 2004).

The presence of DOC in a river system is essential for productive fish habitat, and affects chemical, physical and biological processes, most specifically in the regulation of temperature, light and oxygen profiles (Benoit, 2014; Bilby & Likens, 1980; D. R. J. Moore, 1998; Seekell et al., 2015; Ulseth &

Hall, 2015). Generally, waters that have a greater concentration of DOC will be darker, and the light attenuation affects the temperature, where darker water may absorb solar energy at shallower depths creating a shallow thermocline, which can increase the volume of colder, less oxygenated water in a system (Benoit, 2014). Contrastingly, waters with a lesser concentration of DOC have contributed to a great amount of physiological stress in fish species by potentially increasing pollutant toxicity and exposure to ultraviolet light (Benoit, 2014). DOC is primarily composed of charged molecules that readily combine with other charged chemicals, including organic contaminants that may bioaccumulate in fish (Benoit, 2014; Haitzer, Abbt-Braun, Traunspurger, & Steinberg, 1999; Haitzer, Höss, Traunspurger, & Steinberg, 1998), or trace metals that can precipitate on the gills and inhibit biological processes such as ionoregulation and osmoregulation (D. R. J. Moore, 1998; Wood, Al-Reasi, & Smith, 2011).

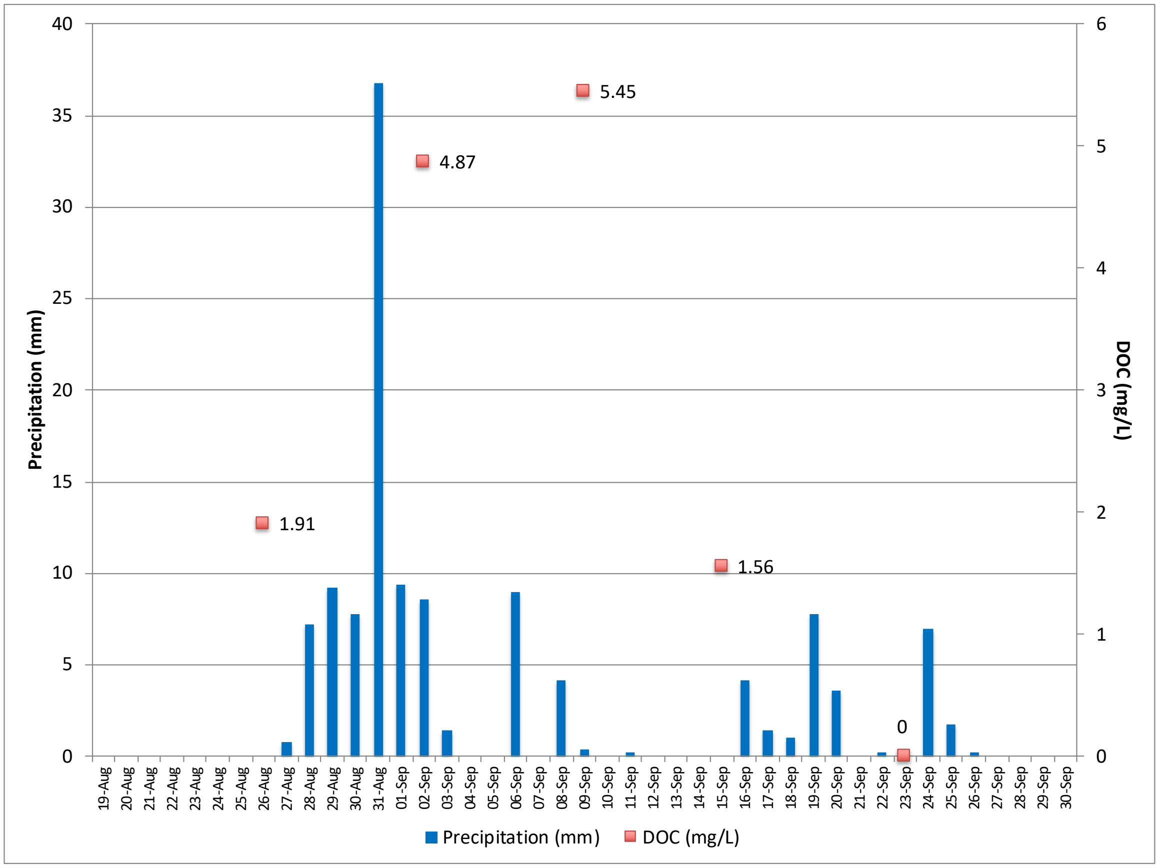
The DOC in the Jordan River was below 5 mg/L at all sites. Typical streams and lakes in British Columbia, historically indicate that DOC levels are below 5 mg/L, with the exception for waters with high natural sources like bogs, or water bodies that are situated close to anthropogenic influences (D. R. J. Moore, 1998). The DOC median was highest at the control Site 1 below Elliot Dam, 3.38 mg/L, and decreased downstream to 1.39 mg/L and 1.43 mg/L through Sites 2 and 3 respectively. The DOC levels were slightly elevated at Site 4, 1.91 mg/L, which may due to run-off from tributaries. The surface water at Site 5 in the waste rock and tailings seep, indicated DOC levels of 0 mg/L. The low levels found at Site 5 may be due to the source of the seep water from the mine portal and through the waste rock and tailings pile, where there would be minimal inputs of organic carbon from dissolved leaf litter, and woody debris.

The metals that displayed elevated values in the Jordan River were zinc, aluminum, copper and phosphorous during the 2015 study. Phosphorous, zinc and aluminum did not exceed provincial limits for freshwater aquatic life at the time of the study, but elevated levels were detected at various sites. Previous scholarship has identified that aluminum concentrations are strongly influenced by organic carbon in a system because it readily combines with the charged molecules in DOC, and can protect fish species from aluminum toxicity (D. R. J. Moore, 1998).

The presence of the three reservoirs on the Jordan River system can complicate DOC cycling and transport and presents a very unique case in the face of toxicity. Reservoirs can trap particulate organic carbon (POC) and alter DOC concentrations downstream (Ulseth & Hall, 2015). POC and DOC are smaller size fractions of coarse particulate organic matter composed of large inputs of terrestrial carbon in the form of sticks, fallen logs, and leaf litter, which enter the hydrological system by run-off or snow melt (Bilby & Likens, 1980). Ulseth and Hall (2015) concluded in their study that DOC concentrations are significantly reduced below reservoirs directly downstream from dams, when compared to the upstream reaches. The three dams on the Jordan River act as carbon sinks, removing POC and DOC from the system, which increases the risk of toxic concentrations of the heavy metals leaching from the mine site downstream. The low levels of DOC are allowing the heavy metal contaminants to flow as free, whereas higher concentrations of DOC would form a complex with these free metals. Research suggests that DOC levels fluctuate with rainfall events, similar to copper, and this relationship was observed in the Jordan River at Site 4 following the initial rains during the sampling period in August 2015 (Figure 14).

**Figure 14**

*Dissolved Organic Carbon Response to Precipitation at Site 4*




*Note.* Water sampling period August through September 2015.

*Environment Canada - Historical Climate Data: Daily Precipitation at Sheringham Point, British Columbia (43°22'36.10"N, 123°55'15.700" W), August and September 2015 (https://climate.weather.gc.ca/climate_data/daily_data_e.html). In the public domain.

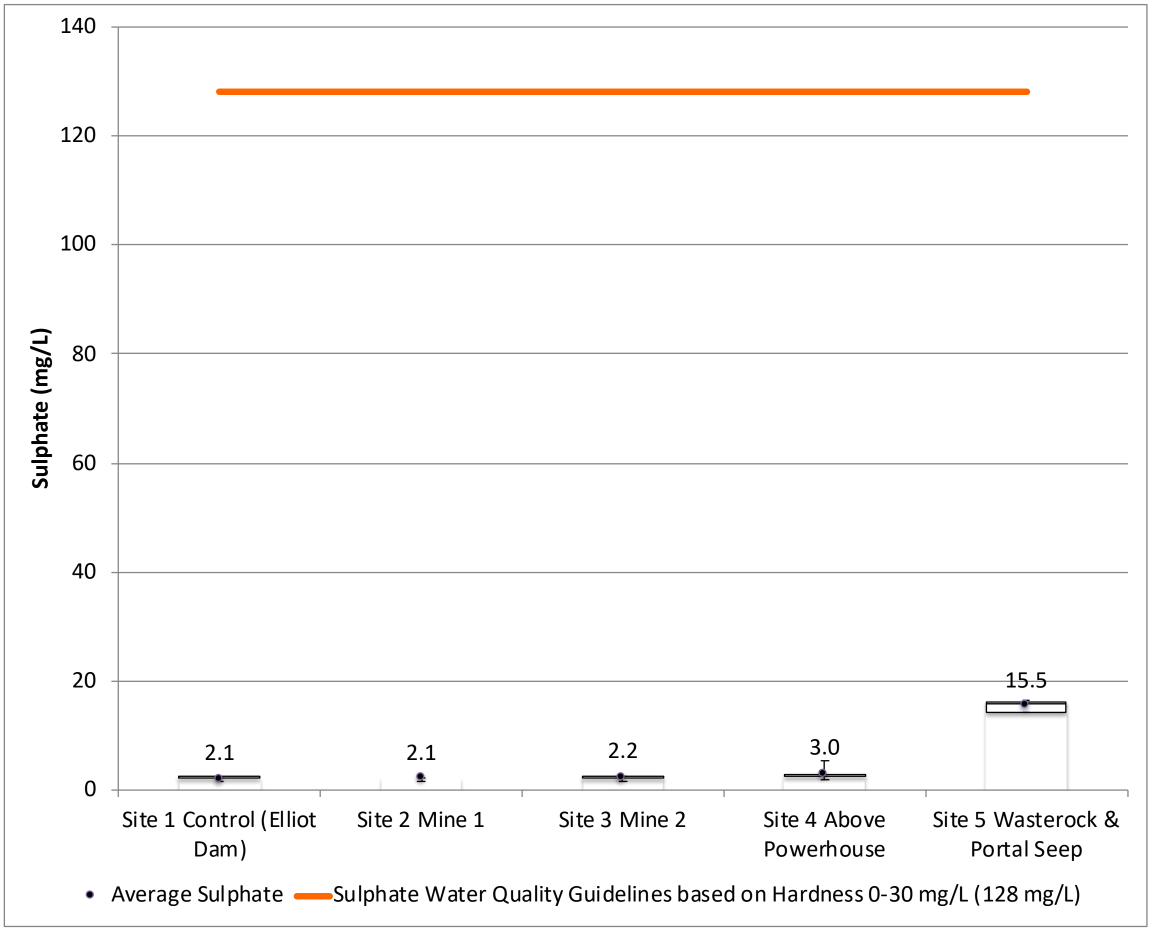
### *Sulphate*

Sulphur occurs naturally in igneous rock formations and enters the environment as soluble sulphates when minerals such as pyrite, barite, gypsum, epsomite, and mirabilite are weathered by water and oxidized (Meays & Nordin, 2013). Toxic levels of sulphates in aquatic environments are primarily associated with active and abandoned mining operations in British Columbia and are a product of AMD. Sulphates are released into the environment when sulphide minerals have been exposed to air and water in mining waste rock and tailings, and the presence of acidophilic bacteria oxidizes minerals such as pyrites, which are commonly associated with copper and gold (Meays & Nordin, 2013). The addition of sulphates in a riverine system increases the mobilization of phosphorous through direct and indirect chemical reactions, leading to eutrophication of surface waters (Zak, Kleeberg, & Hupfer, 2008). There has been few studies on the direct effects of sulphate on fish (Meays & Nordin, 2013), but it has been well documented that high concentrations of sulphates affect aquatic invertebrates such as mortalities in freshwater clams (Soucek & Kennedy, 2005), inhibit aquatic life stages of insects like mosquitos (Conley, Cariello, & Buchwalter, 2010), and aquatic plants and algae (Elphick et al., 2011).

The Ministry of Environment has based the current sulphate ambient WQGs on toxic thresholds of the most sensitive freshwater organism tested - rainbow trout - where sulphate toxicity increased in conditions when hardness increased in controlled experiments (Meays & Nordin, 2013). The current sulphate ambient WQG is based on categories of water hardness and the lethal concentration required to kill 20% (LC20) of the population of rainbow trout, which is 128 mg/L of sulphate for the Jordan River with an average water hardness between 0-30 mg/L (Meays & Nordin, 2013). All the sites within the Jordan River were well below the sulphate ambient WQG for freshwater aquatic life with a slight elevation at Site 5 at the waste rock and portal seep (15.5 mg/L), which may have been due to AMD processes (Figure 15). Sulphate concentrations slightly increased in the main river channel downstream, increasing by 0.90 mg/L, from the control Site 1 to Site 4, further supporting evidence that AMD processes are present in the Jordan River.

**Figure 15**

*30-day Average Sulphate for the Jordan River*




*Note.* Average sulphate over five weekly samples within a 30-day period through September and August 2015, using the Ministry of Environment Ambient Water Quality Criteria. The box plots display the interquartile range of the data, including median, mean, 75$^{th}$ and 25$^{th}$ percentiles (upper and lower respectively). The whiskers display the range of minimum and maximum recorded values.

**Source of Copper and Metal Contamination**

One of the main sources of copper inputs outlined in this study was the waste rock and tailing piles located approximately 1 km upstream from the mouth of the Jordan River at sampling Site 5 (Figure 16). The main access tunnel was completed in 1961 and spans 2.5 km through the basalt and gabbro bedrock canyon that borders the east side of the Jordan River. The waste rock and tailings piles responsible for the seep were derived from building the main access tunnel for the mine, and are estimated to be between 20, 000 and 30, 000 cubic meters (SNC Lavalin, 2016). The north waste rock and tailings pile extends from the main access tunnel downstream along the Jordan River for 120 meters, and the width of the pile at its widest point is 35 meters (Figure 17). The south waste rock and tailings pile is located approximately 40 meters downstream from the north waste rock pile and extends along the Jordan River for 30 meters and measure to be 12 meters high. Excavation of the 5100-level main access tunnel would have involved cutting through copper ore bodies that were to be mined after the tunnel had been constructed. Some of the un-mined copper ore were visibly observed in the waste rock piles during field sampling. In 2015, the Ministry of Environment's Contaminated Sites department ordered Teck Resources to conduct a Primary Site Investigation (PSI) to estimate the extent of contamination caused by the mine. Teck Resources hired SNC Lavalin consultants and published the results of the PSI report in 2017. SNC Lavalin discovered a distinct level of concrete-like tailings in the waste rock pile (SNC Lavalin, 2016). Further discussion led to the conclusion that the underground mill room and sub-marine tailings pipe to the mine was not constructed until a later date, for which a tailings pond would have been required on site (Burt, 2012). The waste rock pile may have been the original site of a tailings pond. The presence of tailings introduces greater concentrations of metal leachate through AMD processes.

**Figure 16**

*Waste Rock and Tailings Piles along the Jordan River*

**Figure 17**

*North Waste Rock and Tailings Pile along the Jordan River*

## Discussion

Copper was the primary contaminant that was targeted in this study due to recommendations of previous research in the Jordan River (BC Hydro, 2003; Wright & Guimond, 2003). The elevated concentrations of metals that are associated with mining include sulphide ores, such as copper, sulphur, and zinc (Gray, 1997). The leaching of metals in the process of AMD are dependent on the host rock geology and can be present in very high concentrations that pollute surface and ground waters to toxic levels. AMD is caused by the oxidation and hydrolysis of metal sulphides, such as pyrite, that have been exposed to the air sourced from un-mined ore in waste rock and tailings (Gray, 1997). Rainfall events can strengthen the processes of AMD providing short time intervals of exposure to water and air, and aid in the transport of metal leachate into main drainage systems (Singleton, 1987). The process of AMD results in the formation of sulphuric acid and iron sulphates, which catalyzes the leaching of metals such as copper, zinc, lead, and cadmium (Barry et al., 2000; Gray, 1997). AMD decreases water quality in receiving waters by lowering the pH and introducing high concentrations of metals in surface and groundwater. The impact of AMD is dependent on the size and sensitivity of the receiving water, and the amount of neutralization and dilution that occurs (Gray, 1997). AMD can detrimentally impact plants, insects, and aquatic animals. The dissolved metals produced in the process of AMD are more toxic to fish and aquatic organisms than the acidity (Barry et al., 2000).

### Waste Rock and Tailings Piles

The waste rock and tailing piles responsible for the source of copper and metal contamination were deposited directly at the river's edge and exhibit steep unstable slopes that are being consistently undercut by the Jordan River, and contaminated material has been sloughing into the river over the last fifty years. Heavy metals from the tailings debris have been detected in an offshore deposit near a provincial park, Sandcut Beach, and were sourced back to the mine site on Jordan River in a study conducted by Kaleen Kilby of the University of Victoria (Kilby, 1991). A total of 1.3 million metric tonnes of waste rock and tailings were generated from the production of the mine and 95% was deposited into the ocean at the mouth of Jordan River (Burke, 2012b). The other 5% of tailings and waste rock were deposited along the banks of the Jordan River.

Furthermore, the geology of the waste rock and tailings piles may be contributing to the elevated concentrations of aluminum, phosphorous, and zinc in surface water. Aluminum, phosphorous, and zinc did not exceed provincial limits for freshwater aquatic life at the time of the study, but elevated levels were detected and noted at various sites. This provides support to earlier findings published in a report by SNC Lavalin (2016), where the spiked metal values were also aluminum, zinc, and copper, in addition to cadmium for surface waters in November 2015. Cadmium was not an elevated metal value in the duration of this study, but similar conclusions were noted for aluminum and zinc. Aluminum naturally occurs in basalts and is commonly monitored in base rock material for road building. Generally, the higher content of aluminum in a basalt road base results in a greater the strength of the road. Aluminum toxicity can be an issue when the bedrock basalt is blasted apart and exposed to surface water, such as the cobbles and boulders of basalt in the waste rock and tailings piles that were excavated from the main access tunnel. Based on the data in this study, it can be concluded that the elevated levels of zinc and phosphorous are a product of AMD due to the increased surface area of sulphide minerals exposed to air and water in the waste rock and tailings piles.

It is recommended that these waste rock and tailings piles be physically removed. The waste rock and tailings piles would need to be stabilized to reduce further impact of erosion and mass movement, in addition to maintaining the biodiversity of surrounding species and removing the sources of contamination followed by long-term monitoring (Venkateswarlu et al., 2016). Although mine remediation is site specific and numerous factors need to be considered, ultimately the waste rock and tailings piles would need to be isolated, contained and excavated for disposal. The mine portals are recommended to be backfilled and sealed to prevent water flow from contacting exposed ore bodies or waste materials in the mine shafts and underground mill room. The method to remove the waste rock and tailings piles may even offer an opportunity to recycle the minerals in the waste rock and tailings material in the process, since the recovery of minerals and modern mining practices have improved by focusing on sustainable practices (Laurence, 2011; Venkateswarlu et al., 2016).

**Coastal Climate and Acid Mine Drainage**

The amount of copper present in a river system is very dependent on the flows which are affected by dams, seasons and tidal flows. As mentioned, the watershed is characterized by a wet maritime climate with very high precipitation seasonally during the winter months. Technically, the wetter seasons will provide greater inputs of copper into the river, as the surface run-off washes over the oxidizing waste rock and tailings into the river. Especially after the waste rock and tailings have been exposed to air, and experience intervals of rain after high temperatures. New surfaces of metal sulphides become exposed and oxidized, increasing the process of AMD. Therefore, the seep copper concentration recorded at Site 5 in the early spring months of this study could be viewed as a lower baseline concentration, since the greatest amounts of precipitation would be expected to occur in the winter months and yield high concentrations of copper contamination. For example, a water sample taken by a consultant hired by BC Hydro on December 5, 2002, found that surface waters sampled at the seep in the waste rock pile reached copper concentrations of 554 ug/L, which is 277 times above the provincial limit (Burt, 2012). The river channel downstream the waste rock piles reached 79 ug/L (39.5 times above the provincial limit) on the same day (Burt, 2012). These findings further support the concept that rainwater events are influencing the contamination in the river. It is expected that copper concentrations would be highest during the wetter winter months and spring freshet if there were heavy snowfall years. Although to date the highest copper concentrations historically recorded in the Jordan River occurred at the Site 5 waste rock seep in October, 2000, where the Ministry of Environment sampled copper values that reached 601 ug/L, about 300.5 times above provincial limits (Deniseger, 2001), more sampling during winter months could be used to further test the precipitation influence. Further research is recommended to monitor the five sites outlined in the study for long-term seasonal and spatial trends of the copper contamination, in addition to exploring areas of high toxicity beyond the areas that are affecting water quality.

**Hydropower Generated Flows on Fish Habitat**

The human-controlled fluctuating flows of the Jordan River present serious complications in predicting dilution factors. The Jordan River has an unnatural flow regime due to the three upstream BC Hydro dams being operated for peak demand. Inconsistent flows and radical fluctuations from 0 to 67 cubic meters per second can be expected daily to meet voltage demands during peak times (Burt, 2012). The demand for power generation can fluctuate seasonally or offset the effects of transmission failures that may occur on the provincial transmission grid system (BC Hydro, 2003). The fluctuating flows alter dilution factors in the river contributing to the inconsistent spiking of metals from AMD has had detrimental impacts on sensitive fish habitats downstream in the past (Burt, 2012). Realistically, these spikes in contamination, such as copper, are beyond provincial water quality thresholds and are toxic to sustaining the life cycles of anadromous fish, such as salmon.

These inconsistent high energy flows are not only destructive to sensitive fish habitat chemically, but physically as well. The inconsistent high energy flows released by the BC Hydro peaking plant scrape spawning gravels from the riverbed in the lower reaches of the Jordan River into the ocean (Burt, 2012). The intermittent and abrupt flows strand juvenile and adult salmon in shallow pools, exposing the vulnerable Jordan River salmon stock to predation by birds, wildlife, and marine mammals. Ideally, the flow release generated by the powerhouse should be altered in such a way that is least destructive physically to fish habitat. The WUP reviews, either scheduled or triggered, could offer an opportunity to negotiate a refit of the powerhouse operations in the lower Jordan River. Specifically, the consideration of engineering the tail race to dissipate the energy of the flow releases to sustain river gravels and spawning habitat in the lower reaches of the Jordan River.

**A Unique Player in Water Chemistry: Dissolved Organic Carbon**

Jordan River presents a very unique and complex case for DOC, and the relationship between the dams and AMD. DOC plays a central role in balancing aquatic chemistry as it can combine with other metals and nutrients, and buffer toxicity to aquatic life (D. R. J. Moore, 1998). Furthermore, the presence of DOC in a river system is essential for productive fish habitat, and affects chemical, physical and biological processes, most specifically in the regulation of temperature, light and oxygen profiles of fish (Benoit, 2014; Bilby & Likens, 1980; D. R. J. Moore, 1998; Seekell et al., 2015; Ulseth & Hall, 2015). The three reservoirs on the Jordan River system complicate DOC cycling and transport. Reservoirs trap large inputs of terrestrial carbon, such as leaf litter, fallen logs, and sticks that have entered by run-off and snow melt. DOC concentrations are significantly reduced below reservoirs directly downstream from dams (Ulseth & Hall, 2015). Low DOC levels are not ideal for freshwater aquatic life in the Jordan River, especially in combination with the leachate of heavy metals from AMD. The low levels of DOC are allowing the heavy metal contaminants to flow as free metals, where higher concentrations of DOC would bond with these free metals and support a healthier fish habitat.

The placement of organic debris dams in the lower reaches of the Jordan River would aid in the accumulation and retainment of organic matter within the river system and allow the organic matter to be processed into finer fractions. Debris dams are an accumulation of organic matter that span the width of the channel, or can be an accumulation of organic matter that extends part way across the channel and forms a major impediment to water flow creating a pool where fine particulate matter and sediment can settle (Bilby & Likens, 1980). Debris dams can be simply a large tree or tree branches that have fallen into a stream channel and lodged against boulders, providing a framework for leaves and woody debris (Bilby & Likens, 1980). The DOC could be monitored in conjunction with the placement of the debris dams, and the use of a Biotic Ligand Model (BLM) could be used to evaluate the bioavailability of metals such as copper, zinc, aluminum, and cadmium. Further research is recommended on the relationship of DOC and metal toxicity in the Jordan River.

**Watershed Groups: Salmon for the Future**

In British Columbia, watershed boards and round tables are emerging as a direct result of local watershed planning processes and are becoming a desired solution to building collaboration and partnerships for resource-based decisions (Brandes & O'Riordan, 2014). British Columbia has recognized the need for local levels of governance to become more engaged in the decision-making process in water policy and has delegated select governance responsibilities to local watershed institutions in the newly proposed *Water Sustainability Act* (Brandes & O'Riordan, 2014). A number of local watershed groups have responded to environmental water quality concerns by targeting salmon as an indicator species of overall watershed health.

One example of a relevant local watershed group in British Columbia is the Tsolum River Restoration Society, which citizens created to preserve and monitor salmon habitat after the remediation of AMD from an abandoned open-pit copper mine that halted operations in 1967 on Mount Washington, British Columbia (Environment Canada, 2017). Similar to the Jordan River, lethal concentrations of copper were leached into the Tsolum River and completely depleted salmon stocks in the year 2000 (Phippen & Obee, 2012). Remediation of the mine was concluded in 2010, when a $4.5 million membrane was installed to seal the surface of the mine site preventing further leaching into the Tsolum River (Environment Canada, 2017). The Tsolum River Restoration Society has developed a partnership with local First Nations, federal, provincial, regional and municipal government agencies, watershed resource stakeholders, and non-profit conservation groups. The goal of the partnership is to restore and maintain fish habitat, including water quality monitoring to meet water quality objectives. Water quality objectives are part of the Ministry of Environment's mandate to manage water quality in

British Columbia, and are prepared for specific water bodies of fresh, estuarine or coastal marine where water quality characteristics may be affected by human activity (Jensen, Sokal, Hilaire, Rieberger, & McQueen, 2012). In 2017, over 84 000 pink salmon returned to the Tsolum River to spawn (Environment Canada, 2017).

Water quality concerns in the Jordan River has resulted in the creation of the JWRT, which includes government agency representatives, First Nations, non-government organizations, academia, and local watershed stakeholders (refer to Chapter 3 of this thesis). The JWRT offers opportunities for open discussion and collaboration on rebuilding a healthy Pacific salmon habitat in Jordan River. The copper contamination needs to be remediated to support healthy salmon populations in the Jordan River. The flows exhibited by the hydro generation on the Jordan River need to accommodate the requirements of a healthy salmon habitat, and possibly complement dilution effects of the copper mine contamination during remediation efforts of the mine. The Jordan River WUP is scheduled for review by 2020 and would provide an opportunity for the JWRT to negotiate flows from the hydro dams that would support a healthy Pacific salmon habitat in the Jordan River. Other options for restoration may include using uncontaminated tributaries to build the capacity for a salmon habitat and enhance the salmon returns in the Jordan River. Water quality objectives should be defined for the Jordan River watershed and continuously monitored alongside programs like the Canadian Aquatic Biomonitoring Network (CABIN), that aim to build a framework for healthy salmon habitat. The JWRT could provide opportunities for academic involvement, salmon enhancement projects and even tourism - by acknowledging the unique history and future success of the Jordan River.

## Conclusion

In British Columbia, resource extraction and land-use practices are projected to increase alongside with climate change, further altering future freshwater quality and quantity. Many studies have focused on examining water quality issues related to resource extraction activity while they are occurring, and less is understood about how resource extraction continues to affect water quality long after it has stopped (Venkateswarlu et al., 2016). This study concludes that resource extraction activities in the Jordan River watershed has heavily impacted freshwater quality and destroyed pre-existing fish habitat. The results demonstrate a continued trend of copper contamination above provincial limits that has very likely persisted in the Jordan River following the beginning of resource development in the watershed in the early 1900s. The presence of the hydro generating system on the Jordan River has further complicated cycling and transport of DOC, which plays an essential role in balancing aquatic chemistry. AMD processes are progressively influenced by seasonal factors such as increased intervals of rainfall, which can be hypothesized to exacerbate with climate change. It is recommended that actions are taken to remove the waste rock and tailings piles along the riverbanks of the Jordan River. Further research is recommended for long-term monitoring of the five sites outlined in the study during mine remediation and habitat restoration, in addition to establishing water quality objectives for the watershed. The placement of organic debris dams in the lower reaches of the Jordan River would aid in the accumulation and retainment of DOC and overall resiliency of the river system. BC Hydro's WUP reviews offer opportunities to negotiate operations of the powerhouse and flow releases in the lower Jordan River to support a healthy Pacific salmon habitat. Water quality concerns in the Jordan River has resulted in the creation of the JWRT, which will aid in open discussions and collaboration on rebuilding a healthy Pacific salmon habitat in Jordan River. The Jordan River provides a considerable case when exploring water quality issues as a result of previous resource extraction practices in watersheds of British Columbia.

**Chapter Two References**


Bakker, K., & Cook, C. (2011). Water Governance in Canada: Innovation and Fragmentation. *International Journal of Water Resources Development*, *27*(2), 275–289. https://doi.org/10.1080/07900627.2011.564969

Barry, K. L., Grout, J. A., Levings, C. D., Nidle, B. H., & Piercey, G. E. (2000). Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(10), 2032–2043. https://doi.org/10.1139/f00-157

BC Hydro. (2002). *Executive Summary: Jordan River Water Use Plan Consultative Committee Report*. https://doi.org/10.1007/s00247-002-0666-y

BC Hydro. (2003). *Jordan River Water Use Plan*.

BC Hydro. (2015). *Water Use Plan Orders Review Program*. Retrieved from https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/gds14-303c-wupor-project-update-med-res.pdf

Benoit, P. O. (2014). *Influence of dissolved organic carbon ( DOC ) on fish production in north - temperate lakes* . McGill University, Macdonald Campus.

Bhuiyan, M. A. H., Parvez, L., Islam, M. A., Dampare, S. B., & Suzuki, S. (2010). Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh. *Journal of Hazardous Materials*, *173*(1–3), 384–392. https://doi.org/10.1016/j.jhazmat.2009.08.085

Bilby, R. E., & Likens, G. E. (1980). *Importance of Organic Debris Dams in the Structure and Function of Stream Ecosystems*. *61*(5), 1107–1113.

Brandes, O. M., & O'Riordan, J. (2014). *A Blueprint for Watershed Governance in British Columbia*.

Burke, H. G. (2012a). *Jordan River mine reclamation and salmon enhancement program (Revision 3)*.

Victoria, BC.

Burke, H. G. (2012b). *Sunro Copper Mine Restart Project*. Retrieved from http://www.sunrocopper.ca/index.htm

Burt, D. W. (2006). *Lower Jordan River fish index study - year 1 results (2005)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2007). *Lower Jordan River fish index study - year 2 results (2006)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2008). *Lower Jordan River fish index study - year 3 results (2007)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2009). *Lower Jordan River fish index study - year 4 results (2008)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2010). *Lower Jordan River fish index study - year 5 results (2009)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. W. (2011). *Lower Jordan River fish index study - year 6 results (2010) and pre/post flow release.* Prepared for BC Hydro, Water Use Planning,

*comparisons (DRAFT)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC.

Burt, D. (2012). *Summary of Water Quality and Biological Data for Anadromous Reaches of the Jordan River*. Prepared for BC Hydro, Water Use Planning

Burt, D.W., and R. Hudson. (2008). *Lower Jordan River inflow monitoring: Year 2 results (2007-2008)*. Prepared for BC Hydro, Water Use Planning, Burnaby, BC. 44 p.

Burt, D.W., and R. Hudson. (2009). *Lower Jordan River inflow monitoring: Year 3 results (2008-2009)*. BC Hydro, Water Use Planning, Burnaby, BC. 40 p.

Capital Regional District. (2014). *Shirley-Jordan River Official Community Plan ROUGH DRAFT*. Retrieved from https://www.crd.bc.ca/docs/default-source/jdf-pdf/shirley-jordan-river-ocp/pps-jdf-2014-09-

01-sjr-roughdraft-2.pdf?sfvrsn=2

Cascadia Biological Services. (2006). *Jordan River spawning assessment and enumeration, Year 1 (Sept 2005 - May 2006): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2007). *Jordan River spawning assessment and enumeration, Year 2 (Sept 2006 - May 2007): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2009). *Jordan River spawning assessment and enumeration, Year 3 (Sept 2007 - May 2008): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010a). *Jordan River spawning assessment and enumeration, Year 5 (Sept 2009 - May 2010): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010b). *No TitleJordan River spawning assessment and enumeration, Year 4 (Sept 2008 - May 2009): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Cascadia Biological Services. (2011). *Jordan River spawning assessment and enumeration, Year 6 (Sept 2010 - May 2011): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Caux, P. Y., Moore, D. R. J., & MacDonald, D. (1997). *Ambient water quality guidelines (criteria) for turbidity, suspended and benthic sediments: technical appendix*.

Chambers, P. A., Kent, R., Charlton, M. N., Guy, M., Gagnon, C., Roberts, E., … Foster, N. (2001). *Nutrients and their impact on the Canadian environment*.

Conley, J., Cariello, N., & Buchwalter, D. (2010). *Preliminary investigations of TDS toxicity and sulfate trafficking in mayflies*. PowerPoint presentation. Presented at SETAC, November 7- 11, 2010. Portland, OR.

De Loe, R., & Kreutziser, R. (2007). Challenging the Status Quo: The Evolution of Water Governance in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 85–103).

Deniseger, J. (2001). *Jordan River Water Quality*.

Deniseger, J., McKean, C. J. P., & Chapman, A. R. (1995). *Water Quality Assessment and Objectives for* *the Tsolum River Basin, Vancouver Island*.

Dore, M. H. (2015). Water Policy in British Columbia. In *Water Policy in Canada: Problems and Possible Solutions* (pp. 235–285). https://doi.org/10.1007/978-3-319-15883-9_8

Ellis, D. (2008). The Role of Deep Submarine Tailings Placement (STP) in the Mitigation of Marine Pollution for Coastal Island Mines. *Marine Pollution: New Research*, 23–51.

Elphick, J. R., Davies, M., Gilron, G., Canaria, E. C., Lo, B., & Bailey, H. C. (2011). An aquatic toxicological evaluation of sulfate: The case for considering hardness as a modifying factor in setting water quality guidelines. *Environmental Toxicology and Chemistry*, *30*(1), 247–253.

Environment Canada. (2015). *Historical Climate Data: Daily Precipitation at Sheringham Point, British Columbia*. Retrieved from https://climate.weather.gc.ca/climate_data/daily_data_e.html%0A

Environment Canada. (2017). Tsolum River Salmon Counts are In. *The Courtenay Comox Valley Record*.

Funk, K., & Burke, H. (2011). *Sunro Copper Mine Restart Project: Jordan River, British Columbia, Canada*.

Google Earth. (n.d.). Jordan River Study Sites and Extent og Copper Mine Main Access Tunnel. Retrieved from https://www.google.com/earth/

Gray, N. F. (1997). Environmental impact and remediation of acid mine drainage: A management problem. *Environmental Geology*, *30*(1–2), 62–71. https://doi.org/10.1007/s002540050133

Gresh, T., Lichatowich, J., & Schoonmaker, P. (2000). An estimation of historic and current levels of salmon production in th enortheast Pacific ecosystem: Evidence of a nutrient deficit in freshwater systems of the Pacific Northwest. *Fisheries*, *25*, 15–21.

Griffith, R. P. (1996). *Biophysical assessment of fish production within the Jordan River Drainage, 1994*. Burnaby, BC.

Haitzer, M., Abbt-Braun, G., Traunspurger, W., & Steinberg, C. E. W. (1999). Effects of humic substances on the bioconcentration of polycyclic aromatic hydrocarbons: Correlations with spectroscopic and chemical properties of humic substances. *Environmental Toxicology and Chemistry*, *18*(12), 2782–

2788. https://doi.org/10.1002/etc.5620181219

Haitzer, M., Höss, S., Traunspurger, W., & Steinberg, C. (1998). Effects of dissolved organic matter (DOM) concentration on organic chemicals in aquatic organisms: A review. *Chemosphere*, *37*(7), 1335–1362.

Hirst, S. M. (1991). Impacts of the operation of existing hydroelectric developments on fishery resources in British Columbia. *Fish Aquatic Science*, *1*(2093), 153.

Hunter, R., Brandes, O. M., & Moore, M. (2014). *A Watershed Governance Case Study. The Cowichan Watershed Board : An Evolution of Collaborative Watershed Governance*.

Hydro, B. (2016). Planning to Improve Fish Habitat on Jordan River. Retrieved April 18, 2016, from Fish and Wildlife Program website: http://fwcp.ca/project/planning-to-improve-fish-habitat-on-jordan-river/

Jackaman, W. (2015). *Map of Mine Tunnels and Copper Ore Bodies in the Jordan River Watershed*.

Jensen, V., Sokal, M., Hilaire, D. St., Rieberger, K., & McQueen, D. (2012). *Water Quality Assessment and Objectives for Osoyoos Lake : A First Update*.

Johnson, C. A., & Thornton, I. (1987). Hydrological and chemical factors controlling the concentrations of Fe, Cu, Zn and As in a river system contaminated by acid mine drainage. *Water Research*, *21*(3), 359–365. https://doi.org/10.1016/0043-1354(87)90216-8

Johnson, D. B., & Hallberg, K. B. (2005). Acid mine drainage remediation options: a review. *Science of The Total Environment*, *338*(1–2), 3–14. https://doi.org/10.1016/j.scitotenv.2004.09.002

Kilby, C. (1991). Investigation for Marine Placers in Juan De Fuca Strait, Offshore British Columbia. *The Gangue*, *36*, 8–9.

Kilby, C. (1994). *Identification of a Small Man-Made Marine Placer*. University of Victoria.

Laurence, D. (2011). Establishing a sustainable mining operation: An overview. *Journal of Cleaner Production*, *19*(2–3), 278–284. https://doi.org/10.1016/j.jclepro.2010.08.019

Lautze, J., De Silva, S., Giordano, M., & Sanford, L. (2011). Putting the cart before the horse: Water governance and IWRM. *Natural Resources Forum*, *35*(1), 1–8. https://doi.org/10.1111/j.1477-8947.2010.01339.x

Meays, C., & Nordin, R. (2013). *Ambient Water Quality Guidelines for Sulphate*.

Ministry of Environment. (1987). *Water Quality Criteria for Copper*.

Ministry of Environment. (2004). Phosphurous: Canadian Guidance Framework for the Managment of Freshwater Systems. In *Canadian Environmental Quality Guidelines for the Protection of Aquatic Life*.

Ministry of Environment. (2013a). *B.C. Field Sampling Manual*.

Ministry of Environment. (2013b). *Guidance for the Derivation and Application of Water Quality Objectives in British Columbia*.

Ministry of Environment & Climate Change Strategy British Columbia. (2018). *British Columbia Approved Water Quality Guidelines for Aquatic Life, Wildlife & Agriculture: Summary Report*. (March 2018), 37. Retrieved from https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

Mitchell, B. (2017). The Hydrological and Policy Contexts for Water in Canada. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (pp. 13–28). Springer International Publishing.

Molle, F. (2009). Water, politics and river basin governance: repoliticizing approaches to river basin management. *Water International*, *34*(1), 62–70. https://doi.org/10.1080/02508060802677846

Moore, D. R. J. (1998). *Water Quality Ambient Water Quality Criteria for Organic Carbon in British Columbia*.

Moore, M.-L., Shaw, K., & Castleden, H. (2018). We Need More Data! *Water Alternatives*, *11*(1), 142–

162. Retrieved from https://poliswaterproject.org/files/2018/02/Art11-1-8.pdf

National Research Council. (1996). *Upstream: Salmon and society in the Pacific Northwest*. Washington, D.C.

Nehlsen, W., Williams, J. E., & Lichatowich, J. A. (1991). Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. *Fisheries*, *16*(2), 4–21. https://doi.org/10.1577/1548-8446(1991)016<0004:PSATCS>2.0.CO;2

Olsen, B. (2016, December 2). Personal interview with J. Edwards.

Phippen, B. ., & Obee, N. (2012). Water Quality Assessment and Objectives for the Tsolum River Watershed. In *Ministry of Environment*.

Seekell, D. A., Lapierre, J. F., Ask, J., Bergström, A. K., Deininger, A., Rodriguez, P., & Karlsson, J. (2015). The influence of dissolved organic carbon on primary production in northern lakes. *Limnology and Oceanography*, *60*(4), 1276–1285. https://doi.org/10.1002/lno.10096

Servizi, J. A., & Martens, D. W. (1987). Some effects of suspended Fraser River sediments on sockeye salmon (Oncorhynchus nerka). *Fish Aquatic Science*, *96*, 254–264.

Shrubsole, D., & Draper, D. (2007). On Guard for Thee? Water (Ab)uses and Management in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water*. UBC Press.

Simms, R., & Brandes, O. M. (2016). Top 5 water challenges that will define British Columbia's future. In *POLIS Project on Ecological Governance, Centre for Global Studies, University of Victoria*. Retrieved from http://poliswaterproject.org/sites/default/files/POLIS-Top5-final-web-v2.pdf

Singleton, H. J. (1985). *Water Quality Criteria for Particulate Matter: Technical Appendix*. Victoria, BC.

Singleton, H. J. (1987). *Water Quality Criteria for Copper Technical Appendix*.

Slaney, P. A., Halsey, T. G., & Smith, H. A. (1977). *Some effects of forest harvesting on salmonid rearing habitat in two streams in the central interior of British Columbia*.

Slaney, T. L., Hyatt, K. D., Northcote, T. G., & Fielden, R. J. (1996). Status of Anadromous Salmon and

Trout in British Columbia and Yukon. *Fisheries*, *21*(10), 20–35. https://doi.org/10.1577/1548-8446(1996)021<0020:SOASAT>2.0.CO;2

SNC Lavalin. (2016). *Supplemental Stage 1 and Limited Stage 2 Preliminary Site Investigation and Preliminary Risk Opinion - Sunro Mine, Jordan River, BC*.

Soucek, D. J., & Kennedy, A. J. (2005). Effects of hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates. 24(5):1204-1210. *Environmental Toxicology and Chemistry*, *24*(5), 1204–1210.

Spear, P. A., & Pierce, R. C. (1979). Copper in the Aquatic Environment Chemistry Distribution and Toxicology. *National Research Council Canada Associate Committee on Scientific Criteria for Environmental Quality Publication*, 13–184. https://doi.org/LC NUMBER: QH545.C6 S63

Ulseth, A. J., & Hall, R. O. (2015). Dam tailwaters compound the effects of reservoirs on the longitudinal transport of organic carbon in an arid river. *Biogeosciences*, *12*(14), 4345–4359. https://doi.org/10.5194/bg-12-4345-2015

Vandecasteele, I., Marí Rivero, I., Sala, S., Baranzelli, C., Barranco, R., Batelaan, O., & Lavalle, C. (2015). Impact of Shale Gas Development on Water Resources: A Case Study in Northern Poland. *Environmental Management*, *55*(6), 1285–1299. https://doi.org/10.1007/s00267-015-0454-8

Venkateswarlu, K., Nirola, R., Kuppusamy, S., Thavamani, P., Naidu, R., & Megharaj, M. (2016). Abandoned metalliferous mines: ecological impacts and potential approaches for reclamation. *Reviews in Environmental Science and Biotechnology*, *15*(2), 327–354. https://doi.org/10.1007/s11157-016-9398-6

Victoria Daily Times. (1964, January). January 7-8, 1964: Dam Burst/Flooding, Jordan River. *Victoria Daily Times*.

*Water Sustainability Act*. SBC, (2014). c 15 http://www.bclaws.ca/civix/document/id/complete/statreg/14015

Wood, C. M., Al-Reasi, H. A., & Smith, D. S. (2011). The two faces of DOC. *Aquatic Toxicology*, *105*(3-4 SUPPL.), 3–8. https://doi.org/10.1016/j.aquatox.2011.03.007

Wright, M. C., & Guimond, E. (2003). *Jordan River Pink Salmon Incubation Study*.

WWF-Canada. (2017). *A National Assessment of Canada's Freshwater: Wateshed Reports*.

Yin, R. K. (2009). Case Study Research: Design and Methods. In L. Bickman & D. J. Rog (Eds.), *Essential guide to qualitative methods in organizational research*. https://doi.org/10.1097/FCH.0b013e31822dda9e

Zak, D., Kleeberg, A., & Hupfer, M. (2008). Sulphate-mediated phosphurous mobilization in riverine sediments at increasing sulphate concentration, River Spree, NE Germany. *Biogeochemistry*, *80*, 109–119.

## Appendices

**Appendix 1: Jordan River Field Card**

<table>
<tr><td colspan="4">Site ID:</td></tr>
<tr><td>Names:</td><td colspan="2">Date:<br><br>Time:</td><td>GPS:<br>N<br>W<br>Elev:</td></tr>
<tr><td>Photo #s:</td><td>Reg. Sample / Duplicate</td><td>Sediment #:</td><td>Location:<br><br><br>Site #:</td></tr>
<tr><td>pH:</td><td colspan="2">Temp:</td><td>Salinity:</td></tr>
<tr><td>TDS:</td><td colspan="2">Conductivity:</td><td>Aspect:</td></tr>
<tr><td>Slope:</td><td colspan="2">Weather:</td><td>Water colour:<br><br>Water height:</td></tr>
<tr><td>Precipitate:</td><td colspan="2">Algae:</td><td>Flow:<br><br>Pool / Slow / Moderate / Fast / Rapid</td></tr>
<tr><td>Biological life:<br><br>Benthic Invertebrates:</td><td colspan="2">Channel bed: Width:<br><br>Organic/Sand/Gravel/ Cobble/Boulder/Bedrock</td><td>Sediment Sample Location:<br><br>Channel / Gravel bar / Moss</td></tr>
<tr><td colspan="4">Surrounding Observations (channel/geology/mine/debris):</td></tr>
<tr><td colspan="4">Additional Notes:</td></tr>
<tr><td colspan="4">Access Notes (GPS, location):</td></tr>
</table>

## Appendix 2: Water Quality Sampling Schedule and Results

| GPS | SITE LOCATION | SITE # | ID | DATE | FIELD DUPLICATE | STANDARD | CU_mg/L | DCU_mg/L | HARD_mg/L | SO4_mg/L | DOC_mg/L | TSS_mg/L | TURB_NTU | LAB Ph_UNIT | FIELD Ph_UNIT | FIELD TEMP_C | Al_mg/L | P_mg/L | Zn_mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | JR 1000 | 2015-08-25 | | RAY1 | 0.060 | 0.035 | 0.041 | 0.710 | 5.94 | 0.40 | 0.08 | NA | | | | | |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 1001 | 2015-08-25 | | | 0.004 | 0.002 | 6.910 | 1.570 | 2.17 | 0.88 | 1.75 | NA | 7.20 | 15.2 | | | |
| 48°27'2.60"N 124° 1'55.30"W | MINE 1 | 2 | JR 1002 | 2015-08-25 | | | 0.004 | 0.002 | 6.700 | 1.500 | 1.39 | 0.40 | 0.86 | NA | 7.40 | 16.0 | | | |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 1003 | 2015-08-25 | | | 0.004 | 0.001 | 7.480 | 1.470 | 0.09 | 1.17 | 0.97 | NA | 7.30 | 16.5 | | | |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 1004 | 2015-08-26 | 1 | | 0.016 | 0.014 | 8.970 | 1.870 | 1.91 | 0.40 | 0.64 | NA | 8.10 | 15.3 | | | |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 1005 | 2015-08-26 | 2 | | 0.016 | 0.014 | 8.850 | 1.870 | 1.91 | 0.41 | 0.56 | NA | 8.10 | 15.3 | | | |
| | | | JR 1006 | 2015-08-25 | | BLANK | 0.000 | 0.000 | 0.049 | 0.000 | 0.00 | 0.29 | 0.00 | NA | | | | | |
| | | | JR 2000 | 2015-09-02 | | BLANK | -0.008 | 0.000 | 0.000 | 0.000 | 0.00 | 0.13 | 0.14 | 7.04 | | | -0.010 | -0.010 | 0.004 |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 2001 | 2015-09-02 | | | -0.008 | 0.000 | 6.140 | 2.180 | 5.45 | 0.67 | 0.99 | 6.31 | 7.20 | 13.1 | 0.130 | -0.010 | 0.007 |
| 48°27'2.60"N 124° 1'55.30"W | MINE 1 | 2 | JR 2002 | 2015-09-02 | | | -0.008 | 0.000 | 5.440 | 2.270 | 3.77 | 0.67 | 0.55 | 6.52 | 7.00 | 12.6 | 0.074 | -0.010 | 0.006 |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 2003 | 2015-09-02 | | | 0.009 | 0.005 | 6.260 | 2.480 | 3.12 | 0.27 | 0.48 | 6.67 | 7.10 | 13.6 | 0.091 | -0.010 | 0.005 |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 2004 | 2015-09-02 | 1 | | 0.009 | 0.005 | 7.600 | 2.570 | 5.71 | 3.92 | 0.49 | 6.76 | 7.40 | 12.6 | 0.086 | -0.010 | 0.007 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 2005 | 2015-09-02 | | | 0.429 | 0.065 | 50.500 | 14.400 | 0.00 | 1.53 | 0.49 | 6.70 | 7.40 | 9.7 | -0.010 | 0.727 | 0.049 |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 2006 | 2015-09-02 | 2 | | 0.012 | 0.010 | 6.790 | 2.670 | 4.03 | 0.61 | 0.42 | 6.97 | 7.40 | 12.6 | 0.070 | -0.010 | 0.004 |
| | | | JR 3000 | 2015-09-09 | | RAY1 | 0.029 | 0.025 | 0.394 | 0.000 | 8.83 | 0.13 | 0.40 | 2.78 | | | -0.010 | 0.025 | 0.111 |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 3001 | 2015-09-09 | | | -0.008 | 0.001 | 4.590 | 2.090 | 6.10 | 0.80 | 0.67 | 6.06 | 7.30 | 12.6 | 0.128 | -0.010 | 0.120 |
| 48°27'2.60"N 124° 1'55.30"W | MINE 1 | 2 | JR 3002 | 2015-09-09 | | | -0.008 | 0.001 | 4.190 | 2.270 | 3.38 | 0.27 | 0.53 | 6.65 | 7.60 | 12.6 | 0.086 | -0.010 | 0.321 |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 3003 | 2015-09-09 | | | -0.008 | 0.003 | 4.880 | 2.380 | 5.84 | 0.13 | 0.41 | 6.66 | 7.10 | 12.6 | 0.071 | -0.010 | 0.127 |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 3004 | 2015-09-09 | | | -0.008 | 0.006 | 5.270 | 2.560 | 5.45 | 0.13 | 0.32 | 6.81 | 7.30 | 13.9 | 0.114 | -0.010 | 0.123 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 3005 | 2015-09-09 | 1 | | 0.380 | 0.070 | 37.500 | 14.400 | 0.00 | 1.87 | 1.46 | 6.31 | 7.70 | 10.3 | 0.070 | 0.680 | 0.160 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 3006 | 2015-09-09 | 2 | | 0.374 | 0.098 | 35.400 | 14.300 | 0.26 | 2.93 | 2.71 | 6.33 | 7.70 | 10.3 | 0.113 | 0.688 | 0.166 |
| | | | JR 3007 | 2015-09-09 | | BLANK | -0.008 | 0.000 | 0.000 | 0.000 | 0.00 | 0.14 | 0.08 | 5.55 | | | -0.010 | -0.010 | 0.114 |
| | | | JR 4000 | 2015-09-15 | | BLANK | -0.008 | 0.000 | 0.277 | 1.460 | 0.00 | 0.15 | 0.11 | 5.66 | | | 2.890 | -0.010 | 2.030 |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 4001 | 2015-09-15 | | | -0.008 | 0.000 | 5.550 | 2.230 | 3.38 | 1.08 | 0.68 | 6.31 | 7.30 | 13.5 | 0.134 | -0.010 | 0.021 |
| 48°27'2.60"N 124° 1'55.30"W | MINE 1 | 2 | JR 4002 | 2015-09-15 | | | -0.008 | 0.000 | 6.080 | 2.280 | 1.30 | 0.62 | 0.50 | 6.47 | 7.70 | 13.0 | 0.112 | -0.010 | 0.008 |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 4003 | 2015-09-15 | 1 | | -0.008 | 0.001 | 6.100 | 2.320 | 1.17 | 1.32 | 0.50 | 6.31 | 7.50 | 12.8 | 0.136 | -0.010 | 0.013 |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 4004 | 2015-09-15 | 2 | | -0.008 | 0.001 | 6.980 | 2.330 | 1.69 | 0.46 | 0.49 | 6.59 | 7.50 | 12.8 | 0.147 | -0.010 | 0.009 |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 4005 | 2015-09-15 | | | 0.012 | 0.008 | 7.550 | 2.600 | 1.56 | 0.30 | 0.35 | 6.66 | 7.60 | 13.5 | 0.151 | -0.010 | 0.008 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 4006 | 2015-09-15 | | | 0.308 | 0.026 | 30.300 | 16.240 | 0.00 | 0.15 | 0.54 | 6.46 | 7.80 | 10.3 | 0.067 | 0.562 | 0.041 |
| | | | JR 5000 | 2015-09-23 | | RAY1 | 0.030 | 0.021 | 0.985 | 0.000 | 4.12 | 1.67 | 0.23 | | | | 0.229 | 0.082 | 0.006 |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 5001 | 2015-09-23 | 1 | | -0.008 | 0.001 | 5.150 | 2.260 | 1.52 | 1.00 | 0.80 | 7.10 | 7.10 | 13.2 | 0.139 | -0.010 | -0.001 |
| 48°28'33.00"N 123°59'56.00"W | ELLIOT DAM | 1 | JR 5002 | 2015-09-23 | 2 | | -0.008 | 0.001 | 4.860 | 2.130 | 0.22 | 0.67 | 0.78 | 7.10 | 7.10 | 13.2 | 0.095 | 0.020 | -0.001 |
| 48°27'2.60"N 124° 1'55.30"W | MINE 1 | 2 | JR 5003 | 2015-09-23 | | | -0.008 | 0.001 | 4.950 | 2.270 | 0.00 | 1.00 | 0.36 | 7.60 | 7.60 | 11.9 | 0.089 | -0.010 | -0.001 |
| 48°26'58.50"N 124° 2'3.40"W | MINE 2 | 3 | JR 5004 | 2015-09-23 | | | -0.008 | 0.001 | 4.880 | 2.270 | 0.00 | 1.00 | 0.39 | 7.50 | 7.50 | 11.6 | 0.106 | 0.026 | -0.001 |
| 48°25'48.20"N 124° 3'5.00"W | ABOVE POWER HOUSE | 4 | JR 5005 | 2015-09-23 | | | -0.008 | 0.005 | 5.460 | 2.400 | 0.00 | 1.00 | 0.52 | 7.90 | 7.90 | 11.4 | 0.095 | 0.042 | -0.001 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 5006 | 2015-09-23 | | | 0.294 | 0.083 | 24.800 | 16.500 | 0.00 | 1.67 | 1.10 | 7.60 | 7.40 | 10.4 | 0.041 | 0.628 | 0.034 |
| | | | JR 5007 | 2015-09-23 | | BLANK | -0.008 | 0.000 | 0.000 | 0.000 | 0.00 | 0.33 | 0.00 | | | | -0.010 | 0.018 | -0.001 |
| | | | JR 6000 | 2015-09-30 | | BLANK | -0.008 | 0.001 | 0.334 | 0.000 | 0.00 | 3.00 | 0.11 | 5.88 | | | -0.010 | -0.010 | -0.001 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 6001 | 2015-09-30 | 1 | | 0.334 | 0.073 | 28.100 | 15.700 | 0.00 | 0.83 | 0.59 | 6.69 | 8.30 | 10.6 | 0.042 | 0.706 | 0.038 |
| 48°25'57.20"N 124° 3'7.90"W | SEEP | 5 | JR 6002 | 2015-09-30 | 2 | | 0.335 | 0.080 | 28.000 | 15.800 | 0.00 | 0.43 | 0.53 | 6.71 | 8.30 | 10.6 | 0.065 | 0.694 | 0.036 |

ICP SCAN OF METALS ADDED SEPTEMBER 9TH, 2015 AFTER FIRST ROUND OF SAMPLING

| | | |
|---|---|---|
| O | ND | NOT DETECTED |
| - | < DL | LESS THAN DETECTION LIMIT |
| mg/L | ppm | parts per million |
| ug/L | ppb | parts per billion |

Detection limit of total copper -0.008 mg/L was averaged to 0.004 mg/L for analysis of total copper due to switch to ICP Scan on September 9th 2015

# Chapter Three: Watershed Planning Carving the Capacity for Watershed Governance


## Abstract

BC Hydro's Water Use Planning (WUP) process is one of the world's most comprehensive hydroelectric dam operational reviews and has served as a model to revise hydropower operating plans with the participation of an inclusive range of stakeholders, rights holders, and up-to-date scientific information, that meets social and environmental goals alongside economic targets. In 2000, BC Hydro initiated a WUP process in the Jordan River watershed. This watershed hosts a wide diversity of water users, including active resource industry stakeholders (mining, forestry, and hydropower), First Nation rights holders, and rural community citizens; which is representative of watersheds in British Columbia with established WUPs. BC Hydro finalized the Jordan River WUP in 2003, which focuses on establishing critical freshwater flows for fish habitat and achieving specific recreational considerations of the local community. However, numerous other issues still remain that were beyond the scope of the WUP process. Consequently, fourteen years after the creation of the WUP, local advocates are still struggling to have their concerns heard by the entity responsible for freshwater flow, BC Hydro, alongside federal and provincial government agencies. Advocates are calling for the creation of a watershed-based group, such as a roundtable, as a mechanism for having greater influence in water planning and governance processes. There is a current movement to create watershed organizations that can be formally supported through new legislation in British Columbia, but questions remain about the capacities of these watershed communities to sustain such a formal institution and if these watershed communities are ready to successfully implement a local watershed governance model. The Gupta et al. (2010) six adaptive capacity dimensions provide a logical framework to explore if these capacities are present such that it could be expected that

local watershed organizations would be effective as society adapts to more watershed-based governance approaches. Thirteen semi-structured interviews were conducted from October 2016 to February 2017. Interviews focused on the WUP and prospective and current members of the Jordan Watershed Round Table (JWRT). The research evaluated whether these six adaptive capacity dimensions are present in watershed communities that have been subjected to water management processes, specifically WUP program.

**Introduction**

Fresh water resources are the Earth's most critical assets. Flowing clean water is essential for functioning and healthy watersheds to provide life, economy and future to society. The attempt to strike a balance between ecological, economic, social and spiritual interests of fresh water has presented many challenges to those responsible for governing. Consequently, water governance has emerged to be one of the most important topics of the 21$^{st}$ century, and has been placed on international agendas as a leading priority that requires immediate action (Lautze, De Silva, Giordano, & Sanford, 2011). Water governance can be defined as the processes and institutions through which water-related decisions are made and uses models, principles and information to make these decisions (Lautze et al., 2011; Reed & Bruyneel, 2010). It is distinct from *water management,* which focuses on the operational and technical aspects of water and is generally more prescriptive with largely defined outcome goals (Bakker & Cook, 2011; Lautze et al., 2011; Reed & Bruyneel, 2010). Recent scholarship has been advocating the consideration of alternative models to empower local communities in water governance (Bakker & Cook, 2011; Brandes, Brooks, & M'Gonigle, 2007; De Loe & Kreutziser, 2007; Hill, Furlong, Bakker, & Cohen, 2008). New approaches to water governance have emerged in the province of British Columbia, where the need for local levels of governance to become more engaged in the decision-making process since select governance responsibilities can be delegated to local watershed institutions through the *Water Sustainability Act (WSA)* (Brandes & O'Riordan, 2014).

The 2016 *WSA* modernizes the former provincial *Water Act* and was created on the basis of recommendations from a number of diverse groups. Modernizations to the *WSA* include the ability to improve management of water as a single resource, protect environmental flows, enhance water quality, and integrate land and water decision-making by enabling innovative approaches to planning and governance (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017). The former *Water Act* neglected to address changing ecological or social issues (Brandes & O'Riordan, 2014; Curran, 2017). The new regulation in the *WSA* focuses on creating a framework for protecting stream health, ground water regulation, water allocation, watershed sustainability planning, monitoring and reporting of major water use, and collaborative governance (Brandes & O'Riordan, 2014; Brandes & Simms, 2018). The *WSA* exhibits a strong feature to adaptively manage water alongside ecological and social conditions, by considering environmental flow standards and permitting adaptive regulation to deteriorating conditions (Curran, 2017). Alongside of the legislative reform there is a current movement to create watershed-based groups like boards and roundtables. These watershed groups can be formally supported through the new regulations in British Columbia, although pilot projects are still ongoing that test how this will be implemented in practice. In the meantime, questions remain about the capacities of these watershed groups to sustain such a formal institution and if these watershed groups are ready to successfully implement a local water governance model.

An example of water management in British Columbia includes BC Hydro's Water Use Planning (WUP) process. The WUP is one of the world's most comprehensive hydroelectric dam operational reviews at the time it was launched and has served as a model to revise hydropower operating plans with the participation of an inclusive range of stakeholders and up-to-date scientific information, that meets social and environmental goals alongside economic targets (Matthews & Hill, 2004; Scodanibbio, 2011). In 2000, BC Hydro initiated a WUP process in the Jordan River watershed (BC Hydro, 2003). This watershed hosts a wide diversity of users, including active resource industry stakeholders (mining, forestry, and hydropower), First Nation rights holders and rural community citizens; which is representative of watersheds in British Columbia. BC Hydro finalized the Jordan River WUP, which focuses on ensuring that sufficient water is flowing for freshwater fish habitats and specific recreational considerations of the local community are met (BC Hydro, 2003). However, numerous other issues still remain that were beyond the scope of the WUP process, including: water quality concerns from contamination by improper disposal of wood waste by the logging industry (Johns, Chan, Gunardi, & Felker, 2014), copper contaminants from previous mines that are no longer active (BC Hydro, 2002, 2003; Capital Regional District, 2014), the extinction of Jordan River pink, coho and chum salmon runs (BC Hydro, 2002, 2003; Capital Regional District, 2014; Hydro, 2016; Wright & Guimond, 2003), and the recognition of local First Nations' watershed values (BC Hydro, 2002). Consequently, fourteen years after the WUP, local advocates are still struggling to have their concerns heard by government decision makers and industry, and have turned to local water governance initiatives by focusing on the creation of a watershed-based group, the Jordan Watershed Round Table (JWRT), as an institutional mechanism for greater influence in water governance, in the hopes this leads to clear changes to water management in the Jordan River watershed (Hydro, 2016).

Recent scholarship has highlighted key conditions and capacities that are important to the success of local watershed governance. Therefore, as an increasing number of watershed groups emerge and in light of the opportunities within BC presented by the legislative changes at the provincial level, there is a need to better understand whether capacity exists to implement a different model for governance. Across the scholarship, one major theme is that local watershed governance will need to be adaptive (Curran & Mascher, 2016; Foerster, 2011; Gregory, Failing, & Higgins, 2006; Joe, Bakker, & Harris, 2017). Scholars have argued the importance for developing adaptive institutions or governance regimes that respond positively to change through mechanisms for close monitoring, learning and improvement (Curran & Mascher, 2016; Foerster, 2011; Gregory et al., 2006; Joe et al., 2017). Adaptive management strategies involve dealing with uncertainty and change in economic, social and environmental conditions (Gregory et al., 2006). A framework that could be useful for assessing watershed governance capacities is known as the Adaptive Capacity framework developed by Gupta et al. (2010).

A study conducted by Gupta et al. (2010) indicates that certain adaptive capacity dimensions need to be present for institutions to stimulate the adaptive capacity of society to respond to climate change and reassess whether institutions need to be redesigned. Gupta et al. (2010) argue that these adaptive capacity dimensions can be applied to different institutions beyond climate change, and provide a methodology to assess whether institutions need to be redesigned by using their "Adaptive Capacity Wheel" (see Chapter 1 for an overview of how the adaptive capacities framework relates to water governance). Gupta et al. (2010) define adaptive capacity as "the inherent institutions that empower social actors to respond to short term and long term impacts either through planned measures or allowing and encouraging creative responses from society both ex ante and ex post", where institutions are defined as a system of rules and decision-making procedures (Yamagata, Sewell, Wasson, & Young, 2001) that are either formal governmental policies or informal social patterns of engagement (Arts & Buizer, 2009). The six adaptive capacity dimensions presented by Gupta et al. (2010) are: variety, learning, room for autonomous change, leadership, resources, and aspects of fair governance.

The Gupta et al. (2010) adaptive capacity dimensions provide a logical framework to assess if these capacities are present as society adapts to changing conditions, such as an institutional shift towards a watershed-based organization. Simply the act of creating institutions in the forms of “boards” is not sufficient, and typically these “boards” are put into place without concern about if these capacities are present. The WUP process provided a water management opportunity to build knowledge about watersheds and engage in participatory structured water management decision-making, which was used by the Province as a means to consider “tradeoffs”. That is, to establish dam flow rates that were economically feasible while considering ecological and social values expressed by the First Nations and stakeholders in the watershed. It could be hypothesized that a watershed with a completed WUP “should” have many of the “adaptive capacities” for effective water governance present. But such a hypothesis has not been explored, and therefore, it is uncertain whether a watershed with a WUP is “ready” for success in implementing the local watershed governance model.

Questions remain about whether these adaptive capacities are present and yet, the Jordan River community begins to push toward local watershed governance. In this research, I have evaluated whether the capacities defined by Gupta et al. (2010) are present in watersheds that have been already subjected to participatory water management processes, specifically the WUP program. In this research, I have addressed: *how does a watershed community address concerns in a watershed planning process, like a WUP, through developed adaptive capacity?*

## Methods

### Case Study Description

The Jordan River watershed is located on the southwest coast of Vancouver Island approximately 72 kilometers from the provincial capital city of Victoria and governed by the Capital Regional District (Figure 18). The total area of the watershed is 165 square kilometers, and its hydrology is influenced mainly through precipitation and limited snowmelt that drains into the Juan de Fuca Strait (BC Hydro, 2003).

**Figure 18**

*The Jordan River Watershed*


*Note.* Reprinted from "Meeting Little Comfort for Jordan River Dam's Path" by A. Smart, 2014, *Times Colonist*. (https://www.timescolonist.com/news/local/meeting-little-comfort-for-jordanriver-residents-in-dam-s-path-1.1664167).

The Jordan River estuary was historically the traditional hunting and fishing territory of the Ditidaht and Pacheedaht First Nation. Pacheedaht settlements populated the mouth of the Jordan River, and were used seasonally to gather food for their community in the area now known as Port Renfrew, B.C., approximately 40 kilometers north of the Jordan River. Resource extraction development began in the Jordan River watershed in the early 1900s and resulted in the displacement of the Pacheedaht First Nation from their traditional hunting and fishing territory. Combined with the effects of resource development, which led to the permanent decline of salmon and wildlife populations in the watershed (Wright and Guimond, 2003) (refer to Chapter 2 of this thesis) these circumstances have resulted in the Pacheedaht no longer being able to hunt, fish or harvest in the watershed. Today, a rural community of 150 non-Indigenous people lives within the watershed.

Jordan River is located within a stretch of provincial parks, coastline hiking trails, and campgrounds that attract high amounts of seasonal tourism. Year-round recreational users frequent the shores of Jordan River to pursue surfing and water sport opportunities. Historically, the Jordan River community was heavily dependent on an economy sustained by resource extraction operations within the watershed. Forestry, mining and hydroelectric operations are still currently active within the watershed today.

**Case Study Context**

***BC Hydro's Water Use Plan***

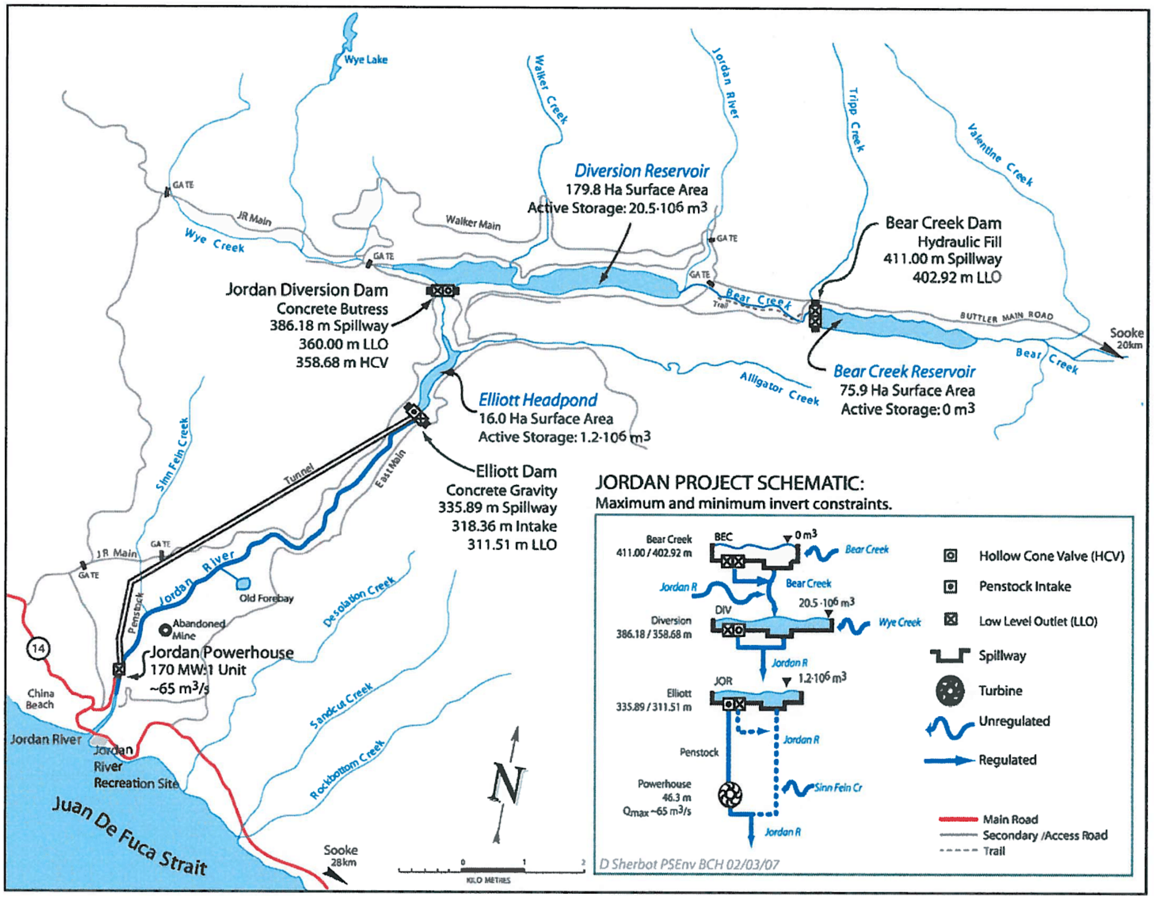
Hydroelectric development along Jordan River was initiated in 1909 and has operated continuously since 1911 (Wright & Guimond, 2003). In 1971, a 175 MW powerhouse was built to replace the original 26 MW powerhouse located on the east side of the Jordan River (Burt, 2012). The current powerhouse is part of a delivery system that has three hydropower dams, two reservoirs, a head pond, and a tunnel penstock delivery system in the Jordan River watershed (BC Hydro, 2003). The dams include Bear Creek Dam, which impounds Bear Creek Reservoir; Diversion Dam, which impounds Diversion Reservoir; and Elliot Dam, which impounds the Elliot Headpond (Figure 19). These generating facilities are part of BC Hydro's integrated generation system, and contribute to the only major hydroelectric development on the southwest coast of Vancouver Island (BC Hydro, 2003). The hydroelectric development can generate up to 175 MW of power, and could potentially sustain approximately 35% of Vancouver Island's total electricity demands (BC Hydro, 2003). However, approximately 80% of the power demands of Vancouver Island are supplied by a submarine cable transmission system from the Lower Mainland (BC Hydro, 2003) and therefore, the current operating role of the Jordan River facility is defined as a “peaking plant” to meet voltage demands during peak times of the day, and offsetting the effects of transmission failures that may occur on the provincial transmission grid system (BC Hydro, 2003). Power generation generally occurs in the early mornings, and afternoons to suit the peak demands of the population living on Vancouver Island, which unnaturally alters the flow in the Jordan River daily.

The operations of the BC Hydro facilities in the Jordan River watershed are operated according to the WUP, including dam releases and fish flows. The Jordan River Water Use Planning process was initiated in April 2000 and completed in November 2001, where the operational changes to the Jordan River BC Hydro facilities in the WUP were based on recommendations of the Jordan River Use Plan Consultative Committee (BC Hydro, 2002, 2003). The committee was comprised of fourteen members that expressed interests in First Nation cultural use and heritage sites, power, recreation, water quality, fish and wildlife, and socio-economic aspects of the watershed (BC Hydro, 2002). The Comptroller of Water Rights revised and finalized the Jordan River WUP in 2003 under the provincial *Water Act* (BC Hydro, 2003). The proposed operating conditions in the WUP were expected to improve habitat for resident fish populations, and increase the quality of ecological habitat downstream in lower Jordan River (BC Hydro, 2003). BC Hydro aimed to commit to a greater base flow that would increase salmonid success in the lower Jordan River by improving water temperature and water quality in the summer months (BC Hydro, 2003). In 2008, BC Hydro installed a fish water release pipe at the Elliot Dam, and an agreement was made through the Jordan River WUP to maintain a year-round base flow release of 0.25 cubic meters per second (Burt, 2012). Due to concerns of the release valve tripping, and potentially destroying downstream fish habitat, a decision was made to keep the valve of the release pipe in a locked open position, which resulted in a flow release of about 0.30 to 0.40 cubic meters per second from the Elliot head pond (Burt, 2012). Prior to 2008, there was no base flow in the Jordan River, except when the dam was spilling during a flood event, which resulted in the downstream fish habitats dependent on tributary inputs (Burt, 2012). Flows in the Jordan River were as low as 10 – 12 litres per second (0.010 to 0.012 cubic meters per second) during the dry summer months (Burt & Hudson 2008, 2009). The lack of freshwater flows in the Jordan River heavily impacted downstream fish habitat and exacerbated cumulative effects of contamination from an abandoned mine site downstream.

The WUP outlined uncertainties and information gaps in the proposed operating procedures. The Comptroller of Water Rights recommended that BC Hydro to implement a monitoring program that would reduce these uncertainties over time by assessing the outcomes of the operational changes and providing additional information that can be used to inform future operating decisions (BC Hydro, 2003). These uncertainties included: a lack of information on establishing minimum base flows to increase downstream ecological habitats, specifically influencing river-bearing rainbow trout; metal toxicity from historic mining operations and critical low flows that may impact the success and survival of spawning and rearing salmonid species; response level of stress to reservoir rainbow trout associated with draw downs, and whether or not discharge reduction enhances surf quality on select weekends in March (BC Hydro, 2003). As a result, a number of projects have been actively conducted in the watershed since 2003 that focus on monitoring the uncertainties outlined in the WUP (Burt, 2006, 2007, 2008, 2009, 2010, 2011, 2012; Cascadia Biological Services, 2006, 2007, 2009, 2010a, 2010b, 2011). A review of the Jordan River WUP is recommended to occur every six years (BC Hydro, 2003), but it was not until 2014 BC Hydro announced that the provincial review of all the WUPs in the province is to commence January 2015 and conclude in 2030 (BC Hydro, 2015).

**Figure 19**

*BC Hydro Facilities in the Jordan River Watershed*




*Note.* Reprinted from *Jordan River Water Use Plan*, by BC Hydro, 2003.

### ***Local Water Governance Initiatives***

The Jordan River community is in the process of creating a watershed-based group (Hydro, 2016) which parallels a recent widespread emergence of community-based watershed governance initiatives in British Columbia (Brandes & O'Riordan, 2014; Moore & Baltutis, 2016; Morris & Brandes, 2013). There has been an emerging dialogue and informal organization for local interests to engage in water decision-making in the watershed. Within that dialogue, discussions have focused on creating a local watershed based group, the JWRT, that involves community members, industry stakeholders, government agencies and Pacheedaht First Nation to collaborate as a mechanism for greater influence in water planning and governance processes in the Jordan River watershed (Hydro, 2016), similar to neighboring watersheds on Vancouver Island, like the Cowichan Watershed Board, and Shawnigan Watershed Round Table (Hunter, Brandes, & Moore, 2014).

**Data Collection**

The following sections will discuss the qualitative data collection, including interview and observational data. In addition to interview and observational data, select material was reviewed to collate all the information openly accessible about the WUP process in the Jordan River watershed, and any literature that may have provided background information on the Jordan River watershed relevant to the motivations of water governance initiatives, such as historic water quality contamination issues, ecological studies of salmon in the Jordan River watershed, physical geography and geology (including mineral occurrence reports and mineral exploration survey maps), industry history of hydropower and mining, historic aerial photos of the watershed, information on watershed-based habitat restoration projects and current watershed plans. Documentary information is almost always required for case study research (Yin, 2009). This was accomplished through academic search engines provided by the University of Victoria and open source key-word searches that recovered grey literature, scientific reports, media, management plans, consultative committee reports, provincial documents, local meeting minutes and environmental assessment documentation of government agencies, funding programs, industry, environmental consultants, and community. Additionally, interviewees provided the researcher with hard copies of reports that were relevant to the research project. Documents ranged in dates from 1919 to 2014. All the documents were reviewed, and applicable sections of the documents were categorized using academic reference manager software, Mendeley, for reference. These documents were not coded in the same way as the interview and observational data, but rather used for verification of facts and to confirm details relevant to the research project.

The observational and interview data techniques, including description of observational data, interview sample design, and demographics of interviewees selected for water governance analysis are described in the following sections.

***Semi-structured Interviews***

A key objective of the research project is to assess the existing capacity for watershed governance in the Jordan River by capturing the variance in perspectives and experiences of a diverse range of watershed actors through interviews. Semi-structured interviews offer flexibility in the informants' answers, as they include open-ended questions with no fixed responses (Ayres, 2008; Dunn, 2010). An interview guide of 12-15 interview questions focused on representatives' perspectives on the previous WUP process in the Jordan River watershed, including historical and current critical challenges in water resource decisions in the Jordan River watershed, and their perspectives on meeting the six adaptive capacity dimensions (Gupta et al. 2010) in the emerging watershed-based group, the JWRT. These questions had a number of follow-up questions and prompts to ensure direction with descriptive and quality responses. The interview guide was composed of a mixture of question types such as: opinions, descriptive, and structured to the six adaptive capacity dimensions outlined by Gupta et al. (2010) to capture the different views of the research topic being discussed with the informant and reflect a quality interview structure (Dunn, 2010).

The mixture of question types probed a variety of responses that capture reflection, sensitive issues, comparison of events, ordering of events and fine details about the research topics (Dunn, 2010). The questions were asked using the "hybrid funnel and pyramid structure" recommended by Dunn (2010) to build rapport and allow the informant to respond comfortably throughout the interview (Roulston, deMarrais, & Lewis, 2003). The "hybrid funnel and pyramid structure" was achieved by asking easy-to-answer descriptive and narrative questions at the beginning of the interview and then transitioning to perspective based, abstract and more complex questions (Dunn, 2010; Roulston et al., 2003). For instance, an interview would begin with the participant's history and current role in the Jordan River watershed, and transition to questions that focused on specific initiatives of watershed governance and the application of the six adaptive capacities (Gupta et al., 2010). Leading questions were avoided to limit bias in the respondent's answers (Ayres, 2008; Dunn, 2010; Roulston et al., 2003). The structure of these questions were asked from a neutral standpoint that did not reflect bias to ensure completely personal responses that are reflective of the interviewee's experience and provide quality data.

A total of thirteen semi-structured interviews with fourteen participants were conducted from October 2016, to February 2017 (one interview included two participants). The interviewees were selected through a purposive sampling strategy (Palys, 2008), where the population was divided into stratified watershed actor groups of interest that either were affiliated with the WUP process in Jordan River or are possibly involved, in some way, with the newly established "JWRT": Industry, Community (including residents), settler Government (multiple scales including regional, provincial and federal), and First Nations. The full possible range of participants was based on those that were actively engaged in the Jordan River WUP process or that expressed interest in the newly emerging watershed-based group at the first meeting on November 2, 2016, hosted by Teck (industry). Then, at least two participants were attempted to be selected from each watershed actor group to create a sample with a fair representation of each group involved with the WUP, or those who were affected by water governance processes in the Jordan River watershed (Dunn, 2010). A “snow ball” sample method was used to reach interviewees beyond the initial contacts in stratified groups, who were recommended by others as important knowledge holders of information relevant to the watershed governance in the basin (Morgan, 2008). Snowball sampling could introduce bias selection of participants, and the limitation of this method is acknowledged by the researcher. Table 4 summarizes demographic information about the participants that were interviewed in the study.

**Table 4**

*Basic Demographic Information of Key Informants*

| Key Informant (KI) | Watershed Actor Category | Involved in the Jordan River WUP | Involved in the JWRT | Other experience relevant to case study |
|---|---|---|---|---|
| **KI1** | Community | No | Yes | Current resident of Jordan River, mineral exploration contractor. |
| **KI2** | Community | No | Yes | Current resident of Jordan River; selected by snowball sample. |
| **KI3** | Community | Yes | Yes | Current resident of Jordan River, and representative on the consultative committee of the Jordan River WUP in 2000; previous fluvial geomorphologist contractor for industry in the Jordan River watershed. |
| **KI4** | Community | No | Yes | Retired industry employee indirectly involved with the scientific studies initiated by the Jordan River WUP; holds a vested personal interest and passion to restore fish habitat in the Jordan River; selected by snowball sample. |

| | | | | |
|---|---|---|---|---|
| **KI5 & KI6** | First Nations | Yes | Yes | Pacheedaht traditional territory, initially not involved consultative committee of the Jordan River WUP in 2000, but currently involved in the review stage of the Jordan River WUP; lead role in a neighboring watershed-based group of the San Juan River in BC. |
| **KI7** | Government | No | No | Provincial scale, participant provided information on the *WSA* and how it applies to the newly emerging JWRT; selected by snowball sample. |
| **KI8** | Government | No | Yes | Provincial scale, responsible for closure of the mine in Jordan River. |
| **KI9** | Government | Yes | Yes | Federal scale, and lead role in a neighboring watershed-based group of the San Juan River in BC, and other watershed-based groups throughout the province. |
| **KI10** | Government | Yes | Yes | Participant previously involved with the T'Souke First Nation during the initial establishment of the Jordan River WUP in 2000; elected regional government official; lead role in other watershed-based groups in BC; lead role in the establishment of a non-profit organization that focuses on salmon restoration; selected by snowball sample. |
| **KI11** | Industry | No | Yes | Mining owner and operator in the Jordan River watershed; selected by snowball sample. |
| **KI12** | Industry | No | Yes | Developing WUPs in other watersheds and involvement in other watershed-based groups in BC, also a participant in the JWRT. |

| | | | | |
|---|---|---|---|---|
| **KI13** | Industry | No | Yes | Historical mining owner and operator in the Jordan River watershed, and current involvement in other watershed-based groups throughout BC. |
| **KI14** | Industry | Yes | Yes | Environmental consultant for both industry and First Nations in the Jordan River watershed; extensively involved in scientific studies since the initiation of the Jordan River WUP process in 2000; involvement in the current WUP review process; lead role in other watershed-based groups in BC; holds a vested personal interest and passion to restore fish habitat in the Jordan River beyond industry role. |

*Note. Identifying information has been removed to protect KI's anonymity.*

There was potential to interview 19 participants, but only 14 participants agreed to take part in the study. The T'Souke First Nation was initially involved in the Jordan River Water Use plan but chose not to participate in this study because Jordan River is outside their traditional territory. The Pacheedaht First Nation of Port Renfrew, B.C. encompass the traditional area of the Jordan River watershed. The Pacheedaht First Nation agreed to partake in this study. There were also two regional and provincial government representatives who participated in the JWRT meetings, who both wished to participate in the study but did not attain approval from their supervisors and provided potential snowball interviewees in their place instead. Two industry representatives for forestry in the Jordan River watershed declined participation in the study due to operational priorities and time constraints of the employees, therefore the perspectives of industry stakeholders that represented forestry were not included in this study. All interviews were recorded, transcribed and coded using qualitative data analysis methodology (Gibson & Brown, 2009).

The interviews focused on the representatives perspectives regarding the WUP process in the Jordan River watershed, and historical and current critical challenges relating to natural resource decisions in the Jordan River watershed. The interviews lasted on average about an hour, as the open-ended approach allowed new themes to emerge. The interviews were primarily conducted in person, but when this was not possible, then interviews were held by phone. Interviews were recorded with hand-written field notes and recordings. The transcription of the field data was processed immediately following the interview (Roulston et al., 2003).

***Observational Data***

Over the course of the data collection period, the researcher gathered additional data by actively participating in six local meetings with participants of the JWRT relevant to watershed planning and governance initiatives in the Jordan River watershed between November 2, 2016 and March 15, 2018. At the meetings, the researcher sought permission to take detailed notes, and followed the University of Victoria's Tri-Council Policy Statement on the Ethical Conduct for Research Involving Humans by introducing herself, the research project, university department, supervisor and the researcher's intention at the meeting. The researcher assured the participants that she would not be making any identifiable observations of the representatives present and would be taking notes relevant to her research project during the meetings. Table 5 provides the meeting dates, objectives, and participant demographics represented at each meeting. Identifying information has been removed to protect the participants anonymity.

**Table 5**

*Description of Observational Data Collected*

| Date | Meeting objectives | Demographics of participants and notes |
|---|---|---|
| **02-Nov-16** | First meeting hosted by Teck regarding copper contamination remediation in the Jordan River watershed. Results of the Primary Site Investigation (PSI) were reviewed. Meeting chaired by the Ministry of Environment. | 2.0 hrs, 15 participants: government representatives (federal, provincial and regional), community residents, First Nations, industry stakeholders (mining, forestry and hydropower) including expert scientists/consultants.<br><br>**Notes:** Initial participant recruitment for the Jordan JWRT followed the conclusion of this meeting. |
| **22-Nov-16** | BC Hydro's Fish and Wildlife Compensation Program (FWCP) update on Coastal Region Watershed Action Plans for the Jordan River Watershed. | 4.0 hrs, 45 participants (including 5 members from the JWRT): community members, government representatives (federal, provincial, regional and municipal), industry stakeholders (forestry and hydropower), First Nations, non-government organizations, expert scientists/consultants from academia, Jordan River WUP, industry, FWCP and government. |
| **31-Jan-17** | First meeting of the JWRT | 2.5 hrs, 17 participants: community members, government representatives (federal and regional), First Nations, non-profit organizations, industry stakeholders (mining and hydropower), expert scientists/consultants from academia, Jordan River WUP, industry, FWCP and government. |
| **18-Apr-17** | JWRT Meeting: Review Jordan River Watershed Restoration Plan and upcoming projects. | 2.5 hrs, 17 participants: Government (regional and federal scales), First Nations, Non-Government Organizations (NGOs), Industry Stakeholders (Mining, Forestry, and Hydropower), Expert Scientists/Consultants (Academia, WUP, Industry, FWCP and Government), and Community Resident Representative. |

| | | |
|---|---|---|
| **21-Jun-17** | Meeting hosted by Teck: Update on copper remediation detailed site investigation (DSI). Meeting chaired by the Ministry of Environment. | 3.5 hrs, 15 participants: Government (regional, provincial and federal scales), First Nations, Industry Stakeholders (Mining), Expert Scientists/Consultants (Academia, industry and Government), and Community Resident Representative.<br><br>**Notes:** Members of the JWRT attended. |
| **15-Mar-18** | JWRT Meeting: Introduction and History of Jordan River Watershed, and introduction of 2-D Habitat Fish Model and Gravel Placement Project. | 2.5 hrs, 13 participants: Community Resident Representatives, Government (federal), Academia, Non-Government Organizations, members of parliament and staff, First Nations, Scientists/Consultants (WUP, Industry, FWCP and Government). |

The meetings exposed the researcher to presentations, conversations, and discussions that led to insights and access to documents for analysis. These experiences were systematically documented through detailed note taking alongside meeting minutes. These notes were later transcribed and coded using qualitative data analysis software.

**Qualitative Analysis**

The interview transcripts and observational data were organized through the qualitative analysis process of transcription and coding using a qualitative research data software program MAXQDA. At first, the researcher went through the interview transcripts and observational notes paragraph-by-paragraph and inductively coded the data to identify key themes, actions, processes, behaviors, concerns, perceptions and definable ideas that emerged from the interview data to identify importance and commonality in the data (Gibson & Brown, 2009; Harding, 2015).

The second stage of coding involved deductive coding using the Gupta et al. (2010) framework, which is based on six capacity dimensions: variety, learning, room for autonomous change, leadership, resources, and aspects of fair governance (Harding, 2015). This stage of coding was “focused coding” (Charmaz, 2008) where the key capacities outlined in the Gupta et al. (2010) framework were used as broader categories. A key word search was conducted in the qualitative data analysis software to select phrases that contained the key words or concepts that were relevant to the six adaptive capacities (Gupta et al., 2010) and were coded under a category. See Table 6 below, as there may be numerous codes within a category with their attached data segments. For example, the adaptive capacity “learning capacity”, was a broad category of codes that contained key words and concepts supported by the Gupta et al. (2010) framework as addressing uncertainties and presence of trust. The transcripts were repeatedly referenced to ensure that codes were not misrepresenting interviewees words or perceptions.

**Table 6**

*Example of Qualitative Data Coding*

| **CATEGORY** | **Examples of code** | **Sample text in transcript attached to code** |
|---|---|---|
| Learning Capacity<br><br>(Gupta et al. (2010) Adaptive Capacity #2) | Discuss uncertainties | Lack of transparency in decisions being made in the watershed |
| | Trust | Then you build the trust |

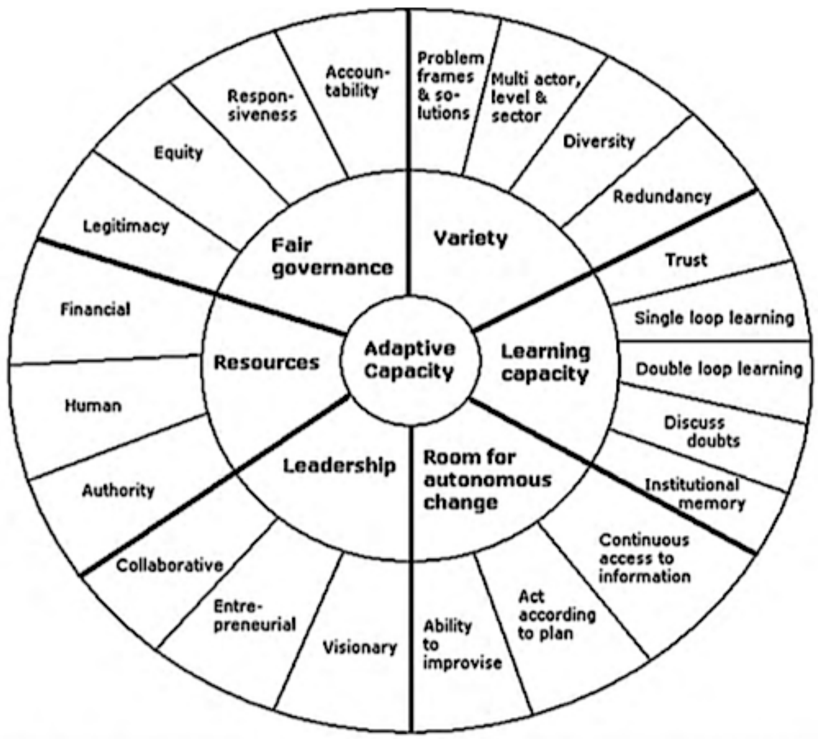
The MAXQDA qualitative data analysis software allowed for queries, often multiple codes and were selected to identify key themes ideas or identify patterns between participants. For example, “trust” and “Water Use Plan” may have been highlighted together to explore trust in the WUP process. There were some themes that did not code directly with focused coding, such as information about the historical events of the Jordan River, major gaps in governance, future solutions, salmon habitat, Indigenous knowledge, or details on specific relationships between participants. These themes emerged unexpectedly but were still valuable to the research project and this data was coded to summarize and create a narrative that outlines key episodes, chronological sequences and define roles in the Jordan River watershed (Dey, 2003) which led to facilitated progressive learning and identified key themes for discussion.

***Final Assessment: Adaptive Capacity Wheel***

The adaptive capacity wheel was a tool designed to assess the adaptive capacities of institutions, where the inner circles displays the adaptive capacity dimensions and the outer circle encompasses the corresponding criteria (Gupta et al., 2010) (Figure 20). A third stage of coding involved deductively coding the qualitative data within the six capacity dimensions to corresponding criteria in the adaptive capacity wheel. A color and scoring scheme are subjectively applied to the wheel to distinguish between high (green: quantitative value +2) to low (red: quantitative value -2) adaptive capacity to assess how institutions, such as the JWRT, influence different aspects of adaptive capacity and highlight areas of discussion and reform.

**Figure 20**

*The Adaptive Capacity Wheel and Color and Scoring System*




| Effect of institution on adaptive capacity | Score | Aggregated scores for dimensions and adaptive capacity as a whole |
|---|---|---|
| | | |
| Positive effect | 2 | 1.01 to 2.00 |
| Slightly positive effect | 1 | 0.01 to 1.00 |
| Neutral or no effect | 0 | 0 |
| Slightly negative effect | -1 | -0.01 to −1.00 |
| Negative effect | -2 | -1.01 to −2.00 |

*Note.* Reprinted from “The Adaptive Capacity Wheel: A method to assess inherent characteristics of institutions to enable the adaptive capacity of society,” by J. Gupta, C. Termeer, J. Klostermann, S. Meijerink, M. van der Brink, P. Jong, S. Nooteboom, and E. Bergsma, 2010, *Environmental Science and Policy, 13*(6), p. 459–471. (https://doi.org/10.1016/j.envsci.2010.05.006). Copyright 2010 by Elsevier Ltd.

The dimensions and criteria in the adaptive capacity wheel are not independent and are designed to be specific to the context being assessed. Therefore, different weights can be assigned to the criteria depending on the context, and the values assigned to the criteria cannot be “objectively” applied, as argued and supported by Gupta et al. (2010). The criteria are subject to interpretation and judgment by the researcher. The researcher used this scoring scheme as a guideline to assess the full extent of the data coded under each category based on understandings from relevant literature,

Overall, the combination of deductive and inductive coding enabled the researcher to identify patterns, themes, and gaps within watershed planning and local water governance initiatives while also testing for specific capacities that were present in the Gupta et al. framework.

***Anonymity***

The researcher sought approval from the University of Victoria Ethics Board to conduct research for human participant research, where the application was approved for a data collection period commencing June 30, 2016 and was renewed annually during the thesis writing period. As part of the University of Victoria’s ethics protocol, the researcher provided participants with a consent form that outlined limits to the participant’s confidentiality. The consent form discussed that participant anonymity may be compromised because the researcher will be naming the “JWRT” and the “Jordan River WUP” in their thesis, and the number of the representatives who fit the selection criteria is small. Therefore, people intimately familiar with these organizations may be able to ascertain their identity, even though identifying characteristics, such as their names, were removed or altered. The participants in this study were informed of their limits of anonymity in this study both verbally and in writing prior to the commencement of the interviews and agreed to partake in the research by signing the consent form.

## Results and Analysis

This section describes key themes and findings using the six adaptive capacities outlined in the Gupta et al. (2010) framework, and the final assessment of the JWRT.

### Adaptive Capacities of the JWRT

#### ***Variety***

Scholars have argued that watershed governance needs to be inclusive of a variety of actors (Brandes & O'Riordan, 2014; Reed & Bruyneel, 2010; Walkem, 2007) because it can lead to collaborative and shared decision-making across multiple disciplines, perspectives, and interests represented within the watershed. Gupta et al. (2010) outline four criteria for assessing the capacity they refer to as variety, which includes the involvement of different actors, levels and sectors of the governance process; variety of problem frames such as multiple opinions and problem definitions; offering diverse solutions or policy options to tackle problems; and the presence of redundancies such as overlapping measures and back-up systems.

**Multiple Actors, Problems and Solutions.** Upon examination of the variety of actors involved in the JWRT, it was observed that five out of the fourteen members had participated in the WUP consultative committee that was formed in 2000. The WUP consultative committee was formed by open invitation from BC Hydro to interested individuals, representatives, water-users, and watershed-based groups, who wanted to partake in an open discussion around interests affected by the hydro operations in the Jordan River watershed. One of the main objectives with the WUP consultative committee was to attempt to engage with local First Nations. However, an industry employee who had been involved in the WUP process in various watersheds on Vancouver Island explained that it was not a mandatory requirement if a certain individual, representative or group decided not to partake in the discussions of the consultative committee. Therefore, during the WUP consultative process in 2000, the Pacheedaht First Nation rights holders chose not to participate planning process of the WUP, but two representatives from a neighbouring First Nation rights holder, the T'Souke First Nation, participated in the WUP consultative committee which met this objective of the WUP (BC Hydro, 2002).

Overall, the formalized consultative committee for the WUP included fourteen members representing the following various interests: power, recreation, cultural use and heritage sites, fish, wildlife, water quality and socio-economic in the Jordan River watershed (BC Hydro, 2002). Some of these same people and interests that had a voice during the WUP process were then carried over to the emerging JWRT, where five out of the fourteen members from the previous WUP consultative committee were now involved with the JWRT seventeen years later. Similarly, the membership on the JWRT was also described as an open invitation to interested individuals or representatives. A community member explained his perceptions of the ideal membership for success on the JWRT when asked how the JWRT will represent diverse actor groups:

> Oh, absolutely everybody . . . it would be all the actual active user groups, industrial user groups within the industry or within the watershed. But it would also include obviously the residents that are living there, it would include user groups such as [non-profit organizations], and surfers who have organizations that actually use the waterfront or who are affected . . . First Nations, who obviously have an interest in that area. There is a water source of spring water that is a registered water source that exists in the lower reaches as well . . . we would want to make sure that the water resource people were aware of what was going on. I think they would need to be involved.

The variety of actors that formed the JWRT were sourced from multiple levels and sectors of governance, where the core participants that formed the JWRT included federal, provincial and regional government agencies, industry stakeholders and consultants, community members, non-government organizations, academia, and First Nations. The key differences between actors involved on the consultative committee of the WUP and the newly established JWRT, was the presence of industry actors representing interests at the JWRT, specifically mining, and the presence and oversight of settler government representatives from multiple scales (including regional, provincial and federal). The diversity of the group brought the presence of multiple opinions, interests and problem frames, such as exploratory mining, interests, hydro power generation, watershed health, mine remediation options, regulatory requirements, and First Nation access to fish salmon in traditional territory. The researcher observed that the diversity of the participants in the JWRT that represented multiple levels and sectors of governance processes not only brought multiple problem frames but enhanced the ability of the JWRT to utilize a variety of expertise at hand and generate a wide range of solutions to tackle problems. As one example, at a JWRT meeting in March 2018, the researcher observed the participants offer expertise, and contacts from their levels of governance to access funding for a proposed habitat project in the watershed.

Although a variety of actors are welcomed and this was stated as being valued by ten of the participants, there were four specific participants that expressed concerns that diverse opinions and interests could affect productivity and unity. For instance, one industry scientist who represented hydropower was specific about needing people that are committed to contributing to the process,

> We're at the infancy there. We have to get the players together. We have to get people to know each other. We need to have the right people from the agencies that are

> proactive and are going to be supportive of the process . . . not going to sit on the side lines but are going to be a participant. And basically, all the people at the Round Table have to come to the understanding that they have to be contributors to the process in whatever way they can. They can't just be onlookers. People have to be able to take an active role. And they have to get along, there can't be any finger pointing.

Another participant from the hydropower industry explained "I believe strongly that this River should be managed by people with a strong local interest and by that I include the Pacheedaht, local residents, and those who have an interest in the fishing resource itself and then also people who affect the River whether it is through river flows, contamination or land use." The industry employee followed up, "I am a bit concerned about sort of a public there, because there is a public that have sat idle for a long time and prepared to accept a dead river and so at what point are they entitled to get up and start criticizing around the Round Table as it tries to get things back? I am not certain". This participant expressed that only individuals or representatives who had a direct interest should participate in local watershed governance to ensure productivity. Further, a Pacheedaht representative explained that public non-government organizations (NGOs), such as environmental non-profit groups, can be beneficial, but sometimes complicate productivity because "NGO activities are more adversarial, rather than working towards the concept of realizing each other's objectives". A perception that emerged from the interview data was an uncertainty on how NGO groups could be involved on the JWRT, moreover, to promote variety in the participants.

**Redundant Measures.** Gupta et al. (2010) use redundancy as a criterion for the adaptive capacity variety, and refer to literature by Weick and Sutcliffe (2001) which explains redundancies as overlapping measures or back-up systems to manage for the unexpected. Weick and Sutcliffe (2001) provide an example of an aircraft being checked in multiple ways by redundant inspections before it is ready to launch. Water governance scholarship has been advocating the importance of recognizing Indigenous knowledge, values, and water rights in decision-making about water through collaborative governance processes (Curran, 2015, 2019). The researcher observed redundancies in the overlapping roles of interest representation among members of the JWRT. For example, there was an industry representative who worked as an environmental consultant for both industry and First Nation rights holders in the Jordan River watershed. This representative held the interests for both parties on the JWRT, and if the First Nations representative or the corresponding industry representative was absent from a meeting, those interests would still be represented on the JWRT. There was a federal government employee who supported the interests of both the public service and First Nation rights holders. Overall, redundant measures were observed in the representation of First Nation rights holders' interests by multiple participants on the JWRT. These criteria of adaptive capacity were assessed to have a positive effect on the adaptive capacity of the JWRT, specifically because First Nation rights holders' interests were consistently represented by multiple participants in local collaborative governance.

**Summary of Variety.** During the data collection period, the researcher observed a variety of watershed actors participate in the JWRT including multiple levels and sectors of government agencies, including regional, provincial and federal agencies. First Nations, non-profit organizations, community members, academia and industry representatives were actively engaged in the JWRT meetings. The variety of actors involved in the JWRT reflected the participants who were previously involved in the WUP consultative process so to that extent, variety has not changed over time. The adaptive capacity "variety" is present in JWRT, including the criteria of a multi-level approach, and decision-making was being reached by a variety of actors that offer diverse perspectives to address a number of different problem frames and solutions (Gupta et al 2010). The researcher observed redundancy in the JWRT in overlapping roles of interest representation on the JWRT, specifically those representing First Nations rights holders' interests. The presence of variety posed challenges, or capacity gaps where members of the JWRT expressed concerns on ensuring productivity and efforts to maintain professional relationships across the various interest groups in the Jordan River watershed. As a result, the adaptive capacity dimension variety was assessed to have a positive effect of the JWRT on adaptive capacity.

***Learning Capacity***

According to Gupta et al (2010), learning capacity as it relates to community groups or "institutions" involves having a capacity to enable actors to learn and improve their institutions. Such a capacity requires: establishing trust amongst one another, having mechanisms or processes for "single loop learning" which allows institutions to learn from past experiences, and "double loop learning" by providing opportunities for actors to challenge the norms, address uncertainties, and a means for stimulating institutional memory by monitoring and evaluating the processes of policy experiences (Gupta et al., 2010).

Overall learning capacity was challenging to assess in the newly emerging JWRT because it had not been established for a long period of time, therefore learning from past experiences for single-loop learning and double-loop learning were limited in practice for assessment in this study. Therefore, analysis focuses on how the members plan on establishing trust amongst watershed actors, address uncertainties and enable monitoring and evaluation programs that may enable institutional memory to assess the learning capacity dimension in the JWRT.

**Establishing Trust on the JWRT.** Trust is a criteria of learning capacity outlined in the Gupta et al. (2010) framework. All fourteen of the interviewees were asked about their perceptions of trust, how they build trust amongst the others on the JWRT and if they could foresee any challenges in gaining trust. One finding that emerged from the interview data was that perceptions of trust were directly linked to transparency. For example, one scientist who represented the hydropower industry stakeholder commented that you build trust by “basically working together and, you know, having an honest forum and not hiding anything.” A community member talked about how distrust can happen,

> Well, I think any distrust that comes out is just the lack of transparency, you know, people are just bound to . . . when you’re not being open about what you are doing it just builds rumors and speculation, and people's imaginations can get a little bit wild and out of control.

A mining industry representative confirmed this relationship of trust and transparency. The mining industry employee explained the successful approach for building trust with members of a watershed-based group is simply being transparent with information at all times, even if there is not a solution, answer or an obvious knowledge gap remains at that point in time. The industry representative explained this successful approach to building trust as:

> I guess just by being accessible, and open, and being willing to tell people “here’s what we know so far, and we still have to do these additional studies, and we haven’t figured this out yet, and we’ll continue to keep you posted.” It’s an approach that we find builds trust and understanding better than the more traditional kind of industry approach of “well, we better not go out with anything until we’ve totally figured out the answer to the problem and have it ready to present.”

Another hydropower industry member talked about how transparency in the WUP has been a major tool in building relationships with community members in watersheds across the province. The industry member felt that “some of my predecessors in the 80’s and 90’s certainly did not have the working relationship with [water] regulators like we do these days”. The mining industry member commented that another approach to building trust within communities is simply employees being present and volunteering with different organizations in the community, because “people get to know the company as people, rather than as a corporation”. The industry representative found that it built familiarity alongside trust.

A Pacheedaht First Nation member felt that trust existed amongst the current members of the JWRT, because representatives were willing to work together and all shared a common interest and passion, which was to restore the salmon habitat in Jordan River. The Pacheedaht First Nation participant explained that historically, this perspective was not always evident with First Nations in the Jordan River, especially during the initial WUP processes in the early 2000s. The First Nation member told the researcher that they did not agree with the way the WUP was conducted and how their role was defined as a Nation within that process. This representative further explained:

> It was not true consultative information sharing or joint decision-making. It was “this is what has been done, and this is what we conclude, and this is what we’re going to do.” And so, that’s not appropriate engagement into an area that we’re so vested into.

The First Nation member felt that their Nation could not “ethically participate in a process that is flawed” during the initial WUP process, because the methods of engagement were far from consultation. It was a more direct approach where industry had already decided what the outcome was and were explaining what was going to be done instead of considering First Nation values in the process. However, at this point in time nearly seventeen years later, the First Nation member claimed that the law had enabled them to participate and engage on multiple scales of governance and that their Nation is better organized internally to strengthen their engagement with the upcoming provincial review of the WUP. According to this participant, the First Nation is fairly satisfied with the current methods of consultation in the current WUP process that have moved away from the traditional approaches in the 2000s, but stated that the processes can still be very delayed and very bureaucratic, and “it’s sometimes hard to get [both] our systems to interact”.

A regional government member  explained that, initially, trust was not established between the interested parties in the Jordan River when issues were brought forward during the WUP process seventeen years earlier: “I think there is a higher level of trust at this point of it, but early in the game I would say very little trust”. This implies that trust had been built over a long period of time, nearly a decade and a half later. Five interviewees were involved in the previous WUP process in the Jordan River from 2000 to 2001, and each of them had expressed their feelings of distrust with industry when they voiced their concerns for the loss of fish habitat in the Jordan River during the consultation process. This member explained his frustration with industry in the WUP as, “they just keep talking, keep talking and keep making hydro and the fish was just more of a nuisance to them then, so they were doing a little bit of work and a little bit of investigation, but after about 10 years I got a little bit frustrated.”

A community member who was involved in the Jordan River WUP process described the experience as,

> It wasn’t a WUP for Jordan River; it was a WUP for BC Hydro to continue doing what they were doing. A lot of people showed up with great expectations in this way. People like “salmon foundation type” people, “fisheries” people, a lot of consultants showed up in the first meeting, thought they could get some work. Some eventually did. But a lot of people thought this was an opportunity to make some changes to the state of what they think was wrong. But it was made clear by BC Hydro…they weren’t going to be denied their permit to use the water. It was just what modifications might be made to the existing use that Hydro made of the watershed and the water, to see if anything could

be incorporated, you know recreation, fisheries etcetera.

The community member talked about why it was considered difficult for industry to agree on changes to the WUP, because a lot of the existing issues regarding mining contamination and anaerobic water caused by the wood waste in the current log booming grounds at the mouth of Jordan River were beyond the scope of the WUP and "too far gone or not Hydro's responsibility to try to rectify". The member felt that "basically people considered it a lost cause that the River had been so contaminated by mine waste, waste rock, mine tailings, and continued acid mine drainage from all that material on the site, on the banks of canyon . . . BC Hydro couldn't do anything about that, wouldn't do anything about that, but it also meant that they didn't have to do anything. They didn't have to provide low flows for fishing because there was no fish. So, they got a pass." The community member commented that originally the T'Souke First Nations attempted to engage in the WUP based on their treaty rights to hunt and fish under the Douglas Treaty, but BC Hydro claimed that their rights did not exist in the Jordan River because there were no salmon, and the River had been destroyed. The First Nations wanted the river returned to its original state, but BC Hydro said they were not legally responsible for the damage caused by the mine. The member said the First Nations decided to not partake in the WUP consultation process, which evidently damaged trust between industry and the neighboring nations. The community member remembers, "when they announced [the T'Souke First Nations] weren't taking part anymore and some people said we should continue on, others thought no, but that's their choice. We did continue on."

This community member also felt that the interested parties did eventually realize that the WUP was not the avenue for initiating change on current environmental issues in Jordan River, but it did bring people together to address the issues at stake in the Jordan River and provide a list of collaborative recommendations to restore the river, even though they may have been beyond the scope of the WUP. It also connected the right people with the same interests and fostered relationships that were built on trust and are still evident today in the JWRT. In the end, BC Hydro agreed to install a fish flow release valve, and address some of the recommendations by the consultative committee including flow releases for surfing at the mouth of the river in the WUP. The community member agreed that industry delivered the WUP according to their mandate: “you know, the WUP guidelines . . . it probably meets everything it says it would. So yes, they did put what the guidelines are supposed to be. But the limitations? I mean, people’s expectations were much higher than what ended up resulting, that’s all.”

**A Foundation for Monitoring and Addressing Uncertainties.** The WUP contributed to the learning capacity of the JWRT by providing a foundation for monitoring and evaluating processes in the Jordan River watershed. Since the completion of the WUP in 2003, the BC Hydro Fish and Wildlife Conservation Program (FWCP) has funded multiple studies, monitoring the uncertainties outlined in the WUP, which have been carried over to the JWRT in addition to being used to make operational decisions in the current WUP monitoring review (Burt, 2006, 2007, 2008, 2009, 2010, 2011, 2012; Cascadia Biological Services, 2006, 2007, 2009, 2010a, 2010b, 2011). The researcher further observed participants on the JWRT openly discuss and address uncertainties that were brought forward at the meetings, specifically involving the remediation options for the mine, the water quality effects of contamination on salmon habitat, and permission issues from land owners to build temporary habitat for supporting productive salmon-rearing. Overall, the JWRT displayed institutional memory processes and openness to uncertainties.

**Summary of Learning Capacity.** Three out of the five criteria outlined by Gupta et al. (2010) for “learning capacity” were present in JWRT, including trust, institutional memory, and discussing doubts, but there were capacity gaps for mechanisms to promote single-loop and double loop learning. The WUP may have affected previous feelings of trust in the watershed historically, but the participants felt that trust already exists amongst the members of the current JWRT. Overall, the WUP had contributed positively to addressing institutional doubts and uncertainties due to the multiple studies conducted in the watershed during the process. As a result, the adaptive capacity dimension learning capacity was assessed to have a slightly positive effect of the JWRT on adaptive capacity.

***Room for Autonomous Change***

Gupta et al. (2010) define the adaptive capacity dimension room for autonomous change as the ability for an institution to allow for actors to adjust autonomously in response to change. This calls for institutions to enable actors to anticipate possible futures, and plan preventative measures against threats through continuous access to information, action plans and capacity to self-organize or improvise with resources at hand (Gupta et al., 2010).

**Access to Information.** Access to scientific information within the watershed allows for continuous monitoring and evaluation which can be used to inform decision-makers and highlight potential challenges in the watershed that can influence preventative planning measures (Armitage et al., 2015; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Robinson, Bark, Garrick, & Pollino, 2015). This was a key theme that interviewees consistently addressed; that is, that decisions in the Jordan River watershed should be made with the support of sound scientific data. A community member explained the importance of continuous access to information as,

> Oh yeah, I think science, it's like of any watershed management activity, science is really the backbone. You need to have real information, and you need to understand what effect that information has. And it is becoming common knowledge now that within an enclosed feature like a watershed, activities that take place affect and impact lots of

> other things that are going on in the watershed, like the salmon resources in the Jordan River watershed.

However, participants had differing views on whether members have access to information on the Jordan River. For example, a federal government worker believed there was a significant amount of scientific information gathered in the Jordan River watershed due to the implementation and consultation activities conducted during BC Hydro's WUP. The representative compared the Jordan River watershed to other watersheds in British Columbia and claimed that "in the Jordan, it's a little different because a lot of this work has been done already. We know the limiting factors and we know the habitat status, so we just need a process that leads us to what we can do, and how we can do it, and how we can evaluate it." Projects that had been completed included annual fish index studies, where funding was allocated through BC Hydro's Fish and Wildlife Compensation Program. The studies had led to the consideration of installing a base flow that would increase salmonid success in the lower Jordan River by improving water temperature and water quality in the summer months (BC Hydro, 2003). In 2008, BC Hydro installed a fish water release pipe at the Elliot Dam, and an agreement was made through the Jordan River WUP to maintain a year-round base flow release of 0.25 cubic meters per second (Burt, 2012). Prior to 2008, there was no base flow in the Jordan River, except when the dam was spilling during a flood event, which resulted in the downstream fish habitats dependent on tributary inputs (Burt, 2012). Therefore, in this example, the scientific information was available, and an informed action had been implemented accordingly.

However, some of the interviewees felt that there was not enough access to scientific information to inform decisions on the Jordan River. A community member expressed,

> Nobody actually tells us anything. As a community we are largely ignored. Considering there is going to be over 200 people who are going to live within the immediate area,

> you think that someone would talk to us. And I think that goes back – a bit of this aside – goes back to the fact that industrial activities within that area were allowed to proceed without much oversight.

The community member refers to not having access to information or any formal updates between industry and the community on the extent of the contamination, fisheries, remediation projects or studies that may be happening within the watershed. The community member asserted,

> There's no information. I don't have any information about the pollution of the river. It's just anecdotal. And then we see people taking samples, and yet I haven't seen those numbers, and I don't know anyone else who has the numbers. So how do you expect to get behind something when you don't even have the real - or any - information on it? Why aren't we given that information? If BC Hydro is so interested in having fish stocks in Jordan River and willing to have contractors come in to count fish, then why aren't they giving us the information on why it's not working? If they're trying to tell us, it's because of pollution?

Information sharing was a common theme that emerged throughout the interviews with participants. A federal government staff member commented that it was important to gather and store all the scientific information available, and in previous watershed groups they have used open source databases such as the Ecological Reports Catalogue (EcoCat) provided by the Province of British Columbia, to share and access information with members participating in watershed based groups. One of the main objectives with creating a JWRT was the opportunity to share and access information in a common place with interested representatives including watershed stakeholders, which engages everyone in collaborative decision-making. The federal employee explained this as, "Everybody has to be brought up to the same level of information and same level of knowledge about what's going on there."

**Act According to Plan.** The researcher observed at meetings of the JWRT that a list of action items would be reviewed to be completed by the next meeting. These action items were often designated to certain representative who had the resources and capacity to complete the action item, for example, representatives were tasked with writing and submitting letters of support to another representative who had experience writing and submitting funding proposals. The composition of members on the JWRT were diverse and offered many opportunities for the watershed- group to use different resources, and contacts of the members to act according to plan and self-organize. Overall, the JWRT fostered the capacity to improvise. For example, if volunteers were needed for gravel spawning placement beds in the river, the Pacheedaht First Nation had contacts for machinery operators that could assist with projects in the Jordan River watershed.

The researcher did observe inconsistencies in achieving deadlines for action items, and often these action items were carried over in the next meetings due to rescheduling or absences of the tasked participants which presented a capacity gap. The JWRT was a voluntary group, so these action items often were not main priorities of the representatives.

**Summary of Room for Autonomous Change**. All criteria outlined by Gupta et al. (2010) for 'room for autonomous change' were present in JWRT, including access to information due to the WUP studies, act according to plan, and the ability to improvise; but there were capacity gaps that resulted from participants having differing views on whether members have access to information on the Jordan River beyond the WUP process, inconsistencies in meeting action items and limitations to improvising with human resources due to voluntary participation. The adaptive capacity dimension room for autonomous change was assessed to have a slightly positive effect of the JWRT on adaptive capacity as each of the criteria were present but displayed limitations.

### *Leadership*

Leadership includes the establishment of long term-visions and goals of the institution, ability to lead by example, and enable collaboration that encourages shared-decision-making amongst different actors (Gupta et al., 2010). Gupta et al. (2010) outline three criteria for leadership capacity including visionary leadership working towards long-term goals, entrepreneurial through leading by example, and collaborative leadership by enabling a variety of actors.

**Visionary Leadership.** A regional government member explained visionary leadership in his experience as working together towards a common goal,

> Well, I think after you have been through a few of these, you start to realize, okay everybody at this table has a vested interest. It's different than yours. And fair enough . . . but that is where it is important to have that goal at the end. And always look at here's where we are going, what we want to accomplish, and then in came everybody's interests, but . . . let's get to that goal.

Nine out of the fourteen interviewees expressed their perspective about having visionary leadership, with results generally showing these nine participants agreeing it meant all the members understanding, agreeing and working towards a common goal on the JWRT. There was lots of positive discussion in both interview and observational data collected by the researcher regarding the goals of the watershed group, including shared values, passion and interests in the restoration of the salmon habitat in the river. Interviewees were confident that these values were already present amongst the interested representatives who wanted to partake in the watershed group. A First Nation interviewee explained in their interview,

> Some of the underlying [stewardship] values… are what I think guides the group because I think there's a lot of common ground in those values. Even if it's not within the mandates, it's within the participants, and the participants are key.

The goal of "stewardship" was echoed across the participants. A First Nation member described further defined their interest as,

> Stewardship. Our community is really focused on habitat restoration, *not* enhancement. Just so you know. And they're very much watershed ecosystem based, and that's the guidance we've always had. You know, elders do not put a band-aid on something to fix it. Nature will prevail.

In the interview data, a common suggestion that was voiced by two different participants in follow-up questions about the visionary nature of the goals of the JWRT, was to incorporate a non-affiliated individual as a lead facilitator who could "champion" the watershed group. A regional government member expressed his concern as,

> Well, it needs somebody that has an interest in the end goal aside from partners that have vested interests… Otherwise, it will turn into a bargaining table . . . "we need this because we need to protect mining interests", and "we need this to protect my interest". And that could overtake the actual goal of what we are trying to do, so it needs somebody in there that has no vested interest at all, other than reaching for the goal of rehabilitating that watershed. I'm not saying they have to be a policeman but should have some type of monitoring or overview of what is happening [on the JWRT]. I do not know who that would be. All the players that would be at the table would have a vested interest that is mostly financially, not that it makes them a bad player, but they are going to be looking out for themselves. It has to be someone or a group that only has one interest in the goal of the habitat, and I guess that is the important thing.

Both participants explained that this individual could champion the visionary goals of the JWRT and would need to be non-biased but have an interest in the watershed group overall so they could keep the group on task and continually working toward the common goal of stewardship.

**Entrepreneurial Leadership and Leading by Example.** The researcher interpreted the presence of entrepreneurial leadership through participants who spoke about leading by examples from past experiences with watershed-based groups. Ten out of the fourteen interviewees referenced their previous learning experiences from other watershed groups and expressed their expectations to apply lessons learned from their experience to the newly emerging JWRT in Jordan River. The interviewees talked about using similar templates, resources, and people from other local watershed-based groups that were successful and applying these experiences to the newly emerging JWRT.

There were four interviewees on the JWRT who had participated in a watershed-based group, the San Juan Round Table, of a neighboring watershed in Port Renfrew, British Columbia that was initiated in 2009. The San Juan Round Table was described as "being related directly to the participants, where the members on the San Juan Round Table were all the landowners, specifically people who operated in the watershed, such as all the forest companies, private landowners, and tenure holders." The goals of the San Juan Round Table were to provide scientific information and monitor the effects of forestry practices, such as bank in stabilization from road building, on salmon habitat in the Gordon and San Juan rivers.

The San Juan Round Table was considered successful by all four of the interviewees, because the forest companies received feedback on their forestry practices and allowed for change in operations that led to an increase in productivity of salmon habitat. A federal government employee explained that establishing partnerships with industry and the users amongst the San Juan Round Table led to major outcomes of positive change in the San Juan and Gordon rivers, by enabling awareness and accountability amongst the watershed users on the San Juan Round Table. The four interviewees who had participated on the San Juan Round Table, equally expressed that the lessons learned from the San Juan Round Table would be a good model for the JWRT.

**Collaboration and Shared Decision-Making.** The watershed actors were asked to define their role on the JWRT, which presented a new set of data that provided details about how the different actors, specifically government and industry, are currently engaging in collaborative leadership within the JWRT. The four industry representatives on the JWRT all responded by defining their role as supportive, but their responses to full or partial participation with the quarterly meetings with the JWRT varied. Two industry representatives expressed that their industry would have limited attendance where their participation would be defined only when operational activities dictated, or when information needed to be shared or gathered from the industry members. An industry representative explained their role in the JWRT as,

> Well, as I said we haven't really decided yet, but it could be, you know, it could be rather than full participation and all aspects for the longer term, it could be just plugging in so that we can share our progress, gather input on the site remediation issues for the copper levels and then if that's something that we're able to just address and get it out of the way as an issue and primarily, you know, be able to say it's dealt with, then we might not necessarily need to be in it for the long run as someone asked. But just for several years until things are addressed hopefully.

This response varied with the feedback of the other two industry representatives, who expressed their industries were very willing to take part in the JWRT and stated that they were interested in what the members had to say and wanted to be engaged in collaborative decisions. These two industry representatives planned on committing to full participation in the

JWRT where they would contribute information, support, and resources through physical presence at the meetings. One of these industry representatives explained, “We’re just going to be there, we’re going to support what’s being done there the best we can”. The two industries that were committing to full participation acknowledged that their presence needed to be more than just advising the members on what operational activities they were doing, but an opportunity to engage, collaborate and openly discuss decisions that were being made in the watershed that would affect the other watershed actors with their industrial operations. One of these industry representatives stated the JWRT was a beneficial resource to discuss and tackle problems of contamination, “there’s a wide variety of headaches now on this river . . . that’s why you have 20 people sitting there with different expertise and interest in different angles. It’s interesting, it’s good, and we like to be part of it”. This specific industry representative had to travel long distances to attend meetings and expressed that they genuinely wanted to address concerns of contamination in the Jordan River.

There were three government representatives that participated in this study each from federal, provincial and regional agencies. The government representatives were asked by the researcher to define their role in the JWRT. The provincial government representative stated that their presence in the JWRT was expected, although they were unclear on what they could deliver, and that “we may not be delivering anything to the table, I don’t know and we will see as things happen, but people want to have some expectation that we’d be there”. This expectation of the governments’ presence on the JWRT was voiced by community participants, where one community member felt that government representatives should be present because there was a shared responsibility for authority over the loss of salmon habitat in the Jordan River amongst federal, provincial and regional scales of government. The provincial government representative said that “it’s very likely that expectations of our Ministry’s [role] will be beyond what we can deliver, because there is an expectation that the Ministry caused the problem and should fix it, but it is more complicated than that." The provincial government representative explained that some of the main complications stem from "standards that have changed over time, and now we know more and have much higher standards today then we did in the 50s, 60s, and 70s." The provincial employee concluded that the standards that took place in the Jordan River in both mining and shutting down the mine would not be allowed today, and it is complicated to revisit the case of contamination decades after these events took place.

The federal and provincial participants also echoed that of industry that their role in the JWRT would be more of "information sharing" and would participate voluntarily and remain "helpful where we can be helpful". The federal government participant planned on being an active member and leader of the JWRT and would offer resources of scientific expertise, programs, and technical advice in salmon restoration. The researcher observed a second provincial government participant that became involved with the JWRT only when required to deliver on-going information on the status of the contamination of the mine and acted as a liaison with the industry responsible for the contamination. This provincial agency offered support but did not actively engage as a member of the JWRT.

**Summary of Leadership.** Visionary leadership was present to some extent on the JWRT, where participants agreed that working towards a common goal of stewardship, and although a specific individual was not identified yet, there were expectations of someone who could "champion" the goals of the JWRT. The four members who had participated on the neighboring San Juan Round Table had expectations to apply lessons learned from their previous watershed governance experience to the JWRT. Overall, both industry and government organizations expressed their willingness to collaboratively support the leadership goals of the JWRT and provide information from their organizations when available, although physical presence at the meetings may not be as consistent as some of the other actor groups and one industry participant was less committed to the process for the long-term. The adaptive capacity for leadership was assessed to have a slightly positive effect of the JWRT due to limitations such as finding a "champion" to lead the visions of the JWRT was not in place at the time of the study, and collaborative efforts from government agencies and industry were limited on what they could deliver to the JWRT.

***Resources Capacity***

Gupta et al. (2010) outline three criteria for assessing resources capacity including exhibiting authority such as the provision of accepted or legitimate forms of power (legal and political mandate), availability of skills and labour through human resources and the capability for the institution to be supported by on-going funding from financial resources.

**Authority.** The authority of the JWRT was explored with participants to understand if the JWRT exhibited any provision of legitimate forms of power. The provision of legitimate forms of power within the JWRT was further explored with participants to better understand how the *WSA* could support the provision of shared decision-making authority. A provincial government employee, who works in developing government policy within the *WSA*, described the *WSA* as allowing either a watershed board, local government or watershed-based group such as the JWRT, to have the capacity and resources to lead a planning process outside the provincial government. The *WSA* allows for the formal appointment of an advisory board that could advise on, for example, environmental flows or establish water objectives. In Section 126(d), decision-making authority can be delegated through regulation to a group, individual or local government in a particular watershed. The provincial government employee explained that this process of decision-making delegation is meant to adapt to unique reporting structures and accountabilities that are specific to certain watersheds, not necessarily a “blanket” approach to all.

The provincial government employee described a successfully delegated watershed-based group as being well established, such as the Okanagan Basin Water Board, which was founded in 1970. The delegation brings an interesting opportunity for local watershed-based groups to become more involved in decision-making processes, but there are only a few groups that have sought out this delegated authority so far, with one being the nearby Cowichan Watershed Board on Vancouver Island. The delegation of decision-making also comes with a legal liability and accountability piece that can cause further challenges for watershed-based groups. The motivations of the watershed-based group would have to be assessed, including any conflicts of interests within the water use of the group and if the group has the capacity to take on legal liability processes which can be challenging.

In the case of the JWRT, which was founded in January 2017, the provincial government employee explained that a watershed-based group in the beginning stages would not be ideal for delegations of decision-making. The human capacities would have to be informally assessed by a committee of the provincial government that delegates the authorities to watershed-based groups under *WSA*. The provincial employee explained a couple of examples of the criteria for assessment such as the knowledge capacity to undertake work, legal capacity to enforce regulations and what type of funding is available to the JWRT, for example, does the watershed-based group have long-term sustainable funding versus project-based funding? At this point of the study the JWRT was dependent on project-based funding, had not been established for a significant amount of time nor is it a legal entity, and unable to fund positions that could deal with legal aspects of delegation of authority, therefore the JWRT would not meet the criteria for delegation of decision-making authorities under the *WSA* at the time of this study.

When the researcher asked the participants in this study whether the JWRT will have delegations of authority under the *WSA,* it was unclear. Since the JWRT was newly established it was difficult to assess delegations of authority pursuant to the *WSA*. Two First Nation representatives described their experience with the *WSA*, as an introducing further complications and challenges in local decision-making, specifically in light of Treaty negotiations. The First Nation participants perceived that during the drafting of the *WSA*, that they were very poorly engaged during the provincial process, and the *WSA* was implemented without addressing any of their concerns, especially regarding water rights and access. The First Nation representative explained that this piece of legislation further fragments their treaty process and provides another "layer" of bureaucracy in decision-making with First Nations. This perception was widely shared by a number of nations and various Indigenous organizations, such as the Union of British Columbia Indian Chiefs (UBCIC), as can be observed in the consultation records from the *WSA* development (Gullason, 2018; Joe et al., 2017).

In the case of the JWRT, which was founded in January 2017, the watershed-based group is still in the beginning stages of development and did not exhibit any legal delegation of decision-making authority.

**Human and Financial Resources.** The interviewees referenced both human and financial resources as critical for successful governance of the watershed group, most specifically regarding funding. A First Nation member explained that they felt confident in the funding available, and the access to knowledge and expertise necessary to restore the river. The First Nation member explained that they have hired technical experts from previous watershed groups, such as the San Juan Round Table and their involvement in the WUP studies have led to contacts of trusted consultants who work for their Nation.

A federal government employee stated that funding was not going to be an issue, and that it would be readily available, because this participant had previous experience securing funding opportunities for similar watershed-based groups, including federal funds for salmon restoration and habitat. The federal employee emphasized the importance of having agreement or "buy in" from Round Table members as key to accessing funding sources,

> I think we need partnerships, and I think that the Round Table is going to be probably the key to developing those, we've got, certainly got recovery plans, and restoration ideas. I don't think funding is an issue. I think there's enough funding programs out there where we've put together a thoughtful, engineered, and justified proposal, I think funding will come. It's just making sure that everybody's onside and that's exactly why a Round Table is needed. But for sure, we need the buy-in, and we need the membership around the table. We need their openness to developing partnerships.

In December 2016 during the data collection period, the emerging JWRT had been granted funding to conduct a feasibility study of a side channel that could potentially support a salmon-spawning tributary that would not be influenced by mining contamination. However, the partnerships between the landowners was not established and the existing landowners were not willing to cooperate with the JWRT. In this situation it was not the funding resource, but the lack of support and partnerships that was stalling projects in the watershed.

A federal government employee believed that beyond funding, human resources were still needed, including capacity to ensure the inclusion and implementation of the First Nation's ways of knowing, more science-based studies and a facilitator or "champion" to lead the JWRT. The federal government employee felt that it was "fine to have a rotating chair, but you really need somebody to make sure there are agendas, and venues, and who keeps on top of the action items, and all those things." A community member believed that both human and financial resources such as expertise and funding were still needed, and that members of the watershed group should be tasked to gather experts who held strengths in certain fields, for example estuary restoration biologists, who could conduct studies in the watershed. The community member believed that "there should be a lot of funding to generate information". Another community member expressed that the watershed group should "put together an organization that can not only transfer information but can also be used to raise funds, that can be used for educational purposes, and that can be used to fund clean-up work using local volunteers as human labour." An industry scientist also echoed this idea, and referenced their previous experience on the San Juan Round Table, "what we've always wanted for the San Juan was to have a slush fund, or have a fund that people could feed into so there's money available when you need to do a study and you don't have to maybe get held up for 6 months while you're looking for funding. If you had a source of funding available that can be tapped into when everybody agreed to do something . . . It would have to be held in some way that's agreeable to everybody." The industry scientist suggested that ideally this would work best for emerging projects in the Jordan River, and would be adaptive to maintaining productivity.

**Funding and Scientific Studies Founded by the WUP Process.** A First Nation interviewee commented that it was initially challenging to secure funding for proposals for gathering scientific data in the Jordan River with BC Hydro's Fish and Wildlife Compensation Program prior to the assemblage of the JWRT because the "baseline data wasn't there at first, so they had to backtrack". It was almost required to have baseline scientific data to support an argument for fish or habitat studies in the Jordan River, but they felt that funding was eventually granted due to expressed public interest at the WUP consultations with BC Hydro. Otherwise, it may have been challenging to conduct scientific studies in the Jordan River. The First Nation member strongly supported that decisions need to be based off current scientific studies, "there's no really any other way to look at it" and funding was granted based on the scientific information available. In addition, a retired industry employee also felt that funding had been granted to the Jordan River watershed because they thought that "BC Hydro had a bit of a guilty conscious about Jordan River in a sense that it had spent a lot of money on other drainages on the Island such as the Puntledge, Campbell River, and Jordan River was a bit of an orphaned child. And so overall, it was also a small drainage compared to the others, so it had not been very well funded relatively, until after the WUP process was completed." Since the completion of the WUP in 2003, there have been multiple fish index studies conducted, which have been used to make operational decisions in the current WUP monitoring review. The WUP contributed to the capacity for financial and human resources because various scientific studies and data were generated with a diverse range of experts, and funding opportunities followed the scientific information.

**Summary of Resources.** The JWRT does not exhibit any form of legitimate provision of authority through legal or political mandate. The financial resources are project based, which is not sustainable, consistent or long-term. It was evident that there was a capacity gap, where funding was needed to build scientific data, and in turn then arguments could be made for proposals for funding based on the scientific information available. However, as expressed by participants, the WUP process built the financial and human resources capacity for the JWRT. The adaptive capacity resources were assessed to have a slightly negative effect of the JWRT due to these limitations.

***Fair Governance***

The adaptive capacity for fair governance criteria includes establishing legitimacy through public support and acceptance, equity that is reflected in fair institutional rules, transparency of institutional processes, responsiveness of the institution to different voices of society, and accountability in institutional procedures (Gupta et al., 2010).

**Legitimacy.** An industry scientist on the newly formed JWRT believed that the public should be engaged in river restoration efforts of the JWRT and information should be shared through evening power point presentations, media releases in the newspaper and posted signage in the watershed to increase public support for the JWRT. A community member and an industry employee both explained that public support of the efforts being made by the JWRT may be key to restoring Jordan River, "I think unless you have public pressure, I don't think anything is going to be done". The more the public is engaged, then the more public pressure will build to clean up and restore Jordan River. A First Nation member explained that if industry is funding projects in the watershed for the JWRT, then there will be a requirement to inform the public of the work being done in the watershed and provide acknowledgements to contributions. At the time of the study, the JWRT was not a legal entity or registered non-profit society, which may have aided in more support and acceptance from the public in legitimacy. The JWRT did have a terms of reference, which is a condition of a legitimate institution or registered society. Overall, since the JWRT was newly established it was difficult to assess legitimacy at the time of the study, but the perspectives expressed above were coded as legitimacy, where there were discussions of mechanisms that could gain public support for the JWRT.

**Equity and Responsiveness.** A community member stated that they were "surprised that Hydro, the forest companies, and anybody currently using [the Jordan River watershed] aren't already in some sort of group, so that at least someone is getting to know it or some of the information is actually filtering into a common area, where if people wanted to go and research or understand what is going on, they could at least have access to the history and current projects going on [in the watershed]". The community member expressed that information prior to the assemblage of the JWRT was unequally available to members of society. A regional government member who had been involved with the WUP process also expressed that information was not shared equally across interested parties in the Jordan River watershed, and it was often only shared between certain stakeholders and industry. The political member thought that "it tends to make you somewhat suspect. When you don't know . . . or have any information, you kind of get [frustrated]". The lack of transparency in the WUP process was noted, and participants expressed this as a capacity gap that would need to be acknowledged with JWRT.

The researcher observed transparency amongst the participants in the JWRT meetings. Participants were able to share their information on new proposals, industry operations, funding opportunities, or stewardship projects in the Jordan River watershed. Participants were able to collectively make decisions, discuss or offer their perspectives on activities that were happening in the watershed due to the transparency of information shared on the JWRT. The JWRT meetings were also a place where historical information about the environmental history of the watershed could be compiled, discussed, shared and updated between all the participants. The transparency of the JWRT led to a better understanding of what activities had historically occurred in the watershed. This transparency of information was limited to the participants on the JWRT, and not available to the public. There were no media releases, official website or social media that could share this information. Overall, it was challenging to assess equity and responsiveness of the JWRT at the time of the study, but there was information gathered from the interviews on what participants expressed was needed to be addressed to attain equity and responsiveness. The researcher observed transparency between the participants on the JWRT.

**Accountability.** A benefit to sharing information amongst participants in a watershed-based group that was mentioned was creating a broader sense of understanding of the biological and operational components of the watershed, since it may create accountability across the participants in the watershed. For instance, an industry scientist claimed,

> I think it's really important for the other sectors like BC Hydro and the forest companies, and whoever else is at the table, to get a greater understanding of the biology of the fisheries that's going on in the systems and understand that aspect. And then I think, also, it's a two-way street. We get to learn about the logging operations and what's important and where it's happening…and I mean I've learned a lot about the operation of hydroelectric just by working around them. Would never have known that otherwise.

The JWRT created formal terms of reference, which is another mechanism that ensured accountability. The terms of reference assigned responsibilities and expectations to members. Five out of the thirteen interviewees mentioned the importance of the terms of reference for the JWRT as a collaborative, decision-making and accountability tool. An industry scientist referred to the terms of reference as "a mandate. So, if everybody understands how the Round Table is structured and what the objectives of the Round Table are…we could foster cooperation and have people that are not going to be pointing fingers at the logging companies or the mining companies." The terms of reference was not in any way binding or holding any legal authority, but basically clarified that if participants wanted to be there it was a voluntary membership and outlined what was expected of them if they chose to accept membership on the JWRT including respectful conduct, decision-making by consensus, and initiative to resolve conflicts. The objective of the terms of reference was to influence open and fair discussion in the JWRT.

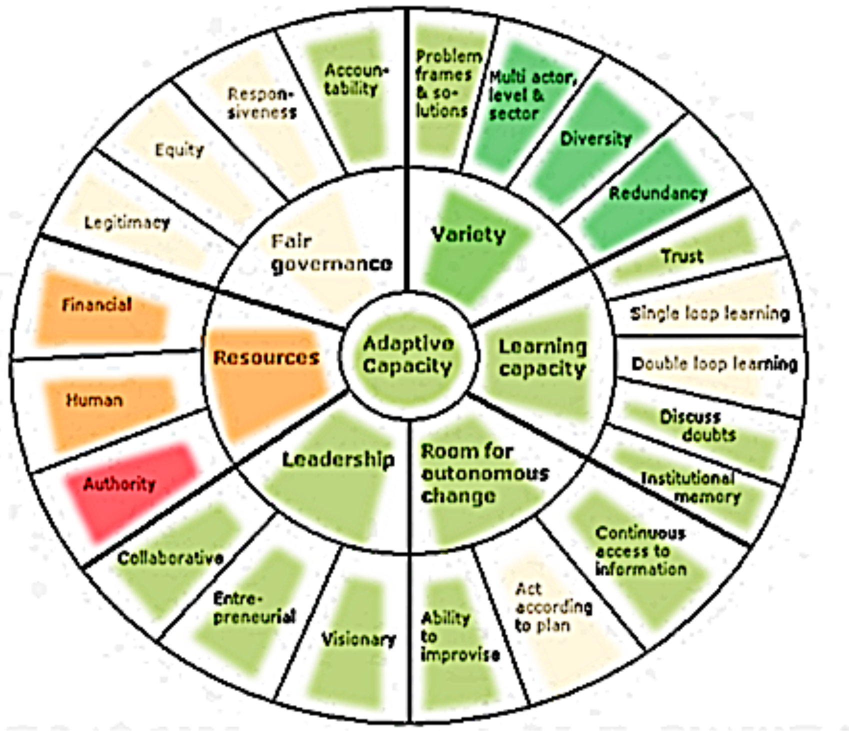
**Summary of Fair Governance.** The findings revealed perspectives about how to build public support to increase legitimacy of the JWRT, but mechanisms to inform and engage the public were limited in practice at the time of the study and therefore, these criteria were difficult to assess. It was also challenging to assess equity and responsiveness of the JWRT at the time of the study, but again information that was gathered from the interviews expressed the need to attain equity and responsiveness. The researcher observed transparency of information between the participants on the JWRT. Accountability was reached by sharing information, roles and responsibilities of the JWRT throughout the members, and agreeing to terms of reference that upholds respectful conduct and willingness to resolve issues and make decisions based on consensus. Based on the limitations of practice on legitimacy, responsiveness, and equity, the adaptive capacity of the fair governance dimension was assessed to have a neutral effect on the JWRT.

**Final Assessment of the JWRT**

Based on the results of this study, the JWRT was assessed by the researcher to have a slightly positive adaptive capacity using the Adaptive Capacity Wheel proposed by Gupta et al. (2010) in Figure 21. The adaptive capacity dimension that scored the strongest was variety, where the JWRT displayed a multiple actor, sector and level approach to address a diverse range of problem frames and solutions. The JWRT exhibited strength in the adaptive capacity dimension leadership, and the corresponding criteria which was assessed to have an overall slightly positive affect. The adaptive capacity dimension for resources was highlighted as an area that could improve with the JWRT. The JWRT lacked sustainable long-term funding and dependent access to human resources that could conduct studies in the watershed.

**Figure 21**

*The Final Assessment of the Jordan Watershed Round Table*




| Effect of institution on adaptive capacity | Score | Aggregated scores for dimensions and adaptive capacity as a whole |
|---|---|---|
| | | |
| Positive effect | 2 | 1.01 to 2.00 |
| Slightly positive effect | 1 | 0.01 to 1.00 |
| Neutral or no effect | 0 | 0 |
| Slightly negative effect | -1 | -0.01 to −1.00 |
| Negative effect | -2 | -1.01 to -2.00 |

*Note.* Adapted from “The Adaptive Capacity Wheel: A method to assess inherent characteristics of institutions to enable the adaptive capacity of society,” by J. Gupta, C. Termeer, J. Klostermann, S. Meijerink, M. van der Brink, P. Jong, S. Nooteboom, and E. Bergsma, 2010, *Environmental Science and Policy, 13*(6), p. 459–471. (https://doi.org/10.1016/j.envsci.2010.05.006). Copyright 2010 by Elsevier Ltd.

## Discussion

The initial WUP process may have been a source of frustration for the participants, especially regarding aspects like trust and uncertainties in the watershed because it did not provide solutions that were being sought by the community at the time. However, based on the findings and ongoing efforts of the JWRT, there are indications that the WUP process may still have contributed to a longer-term capacity because it brought together a variety of people who had vested interests and shared similar values in the watershed. The concerns that were raised on the consultative committee were a topic of fragmented discussion for nearly a decade and a half, before the interested individuals and representatives decided to form a watershed-based group that focused on the stewardship of the Jordan River. The WUP has contributed to watershed governance in the Jordan River, specifically on building the following adaptive capacity dimensions: variety, learning capacity, room for autonomous change, leadership, and resources. The researcher observed a variety of watershed actors participate in the JWRT including multiple levels and sectors of government agencies, including regional, provincial and federal agencies, First Nations, non-profit organizations, community members, academia and industry representatives which were reflective of the participants who were previously involved in the WUP consultative process in 2000. As a result, interests that were represented in the consultative committee of the WUP were carried over to the emerging JWRT, where five out of the fourteen members from the previous WUP consultative committee were now involved with the JWRT seventeen years later. Uncertainties that were raised but not addressed during the WUP process, specifically included concerns regarding the cultural use of the watershed, salmon habitat and water quality contamination and remediation efforts. These interests that were beyond the scope of the WUP at the time and were later categorized as key problems that need to be addressed in the JWRT, especially regarding stewardship in the Jordan River watershed.

The WUP studies are still currently active and have formed a base of scientific information for the JWRT, specifically regarding inflow measurements for fish habitat, and biological productivity monitoring for fish, and are to be used to inform operational decisions in the upcoming review for the future Jordan River WUP. The evaluation of the water quality, and the spatial and seasonal water quality extent of contamination from the abandoned copper mine appeared to be a major knowledge gap in scientific information for the Jordan River (refer to Chapter 2 of this thesis), which was beyond the scope of the WUP. In addition, securing funding for projects in the watershed was an issue, and the requirement for human resources, such as consultants to carry out stewardship projects and scientific studies beyond the WUP required extensive funding. Resources to conduct scientific studies appeared to an area of improvement for the JWRT, although the WUP had contributed to the capacity of both financial and human resources in the watershed.

**The JWRT Moving Forward**

The Gupta et al. (2010) framework proved to be a valuable tool in assessing the adaptive capacities of the JWRT. The Gupta et al. (2010) adaptive capacity dimensions and criteria exhibited extensive supporting literature and was easily applicable to different institutions beyond climate change. The methodology assessed whether watershed-based groups, such as the JWRT, required areas of improvement by using the "Adaptive Capacity Wheel". The Adaptive Capacity Wheel provided a final assessment that visually outlined areas of success and reform. The Gupta et al. (2010) framework was useful assessment tool that could be used by watershed boards and JWRTs experiencing an institutional shift in society, such as a shift from water management to watershed governance-based organizations.

Although the JWRT may not be eligible to receiving delegation of authority under the *WSA,* the JWRT exhibited aspects that would support knowledge capacity and expertise in planning processes and could provide leadership through an advisory board under the *WSA.* The JWRT could be an advisory board as it becomes more established, which over-time could eventually lead to an opportunity to become a delegated decision-making group under the *WSA*. The JWRT could focus on the initial step of becoming a registered non-profit society. Human and financial resources which were assessed as a slightly negative adaptive capacity would need to be addressed, and perhaps the watershed-based group should focus on partnering with local universities for research projects in the Jordan River which could fill funding and science gaps through interested academic units. Universities would be a very valuable resources for the watershed group and could fill knowledge gaps and assist in different areas of research in the Jordan River watershed. This would enhance the capacity of the JWRT to "act according to plan" and complete stewardship projects in the watershed.

**Limitations of the Adaptive Capacity Framework**

A challenge with using the adaptive capacity framework was that the adaptive capacity dimensions and criteria cannot be "objectively" applied, as argued and supported by Gupta et. al (2010). The criteria outlined in the framework and the assessment is always subject to judgment and interpretation by the researcher. Therefore, the results of the research shall not be perceived as concrete or independent of each other, as certain criteria can reinforce each other. For example, human resources are well-supported through financial resources, which therefore would influence the capability of institutions to "act according to plan". Also, there may be criteria outlined in the assessment may be less or more important, which will be specific to the type of the institution being assessed. For example, the JWRT did not find that being responsive to the voices of society or public were a priority of the JWRT.

The Gupta et al. (2010) framework was effective in addressing the research question on how does a watershed community address concerns in a watershed planning process, like the

WUP, through developed adaptive capacity through assessment of the JWRT, but there were some themes that emerged from the data that did not fit directly with adaptive capacity dimensions or criteria in the assessment. These themes included information about the historical events of the Jordan River, major gaps in governance, future solutions, salmon habitat, inclusion of Indigenous rights, knowledge and history; or details on specific relationships between participants (such as conflict or emotions). These themes were still valuable to the research project and were used to create a narrative that outlines key episodes, chronological sequences and define roles in the Jordan River watershed.

**Conclusion**

The WUP has contributed to watershed governance in the Jordan River, specifically on building the adaptive capacity dimensions: variety, learning capacity, room for autonomous change, leadership, and resources. The WUP process in 2000 brought together key players who had vested interests and shared similar values in the Jordan River watershed. The WUP provided an avenue for facilitation and open discussion regarding First Nation cultural use, industrial recreational uses, salmon habitat and water quality concerns that led to key uncertainties discussed in the JWRT. The WUP studies are still currently active and form the base of scientific information for the JWRT. The Gupta et al. (2010) framework proved to be a valuable tool to assess the adaptive capacity of the JWRT. The adaptive capacity dimensions that scored the strongest was variety, where the JWRT displayed a multiple actor, sector and level approach to address a diverse range of problem frames and solutions. The JWRT exhibited strength in the adaptive capacity dimension leadership, and the corresponding criteria which was assessed to have an overall slightly positive affect. The adaptive capacity dimension for resources was highlighted as an area that could improve with the JWRT. The JWRT lacked sustainable long-term funding and dependent access to human resources that could conduct studies in the watershed. The JWRT does not meet the criteria to exhibit any legal delegation of decision-making authority. If the JWRT is seeking authority in collaborative decision-making in the watershed, then it needs to meet specific criteria for delegations under the *WSA*, including long-term funding and the capacity to take on legitimate action in the watershed.

**Chapter Three References**

Armitage, D., de Loë, R. C., Morris, M., Edwards, T. W. D., Gerlak, A. K., Hall, R. I., … Wolfe, B. B. (2015). Science–policy processes for transboundary water governance. *Ambio*, *44*(5), 353–366. https://doi.org/10.1007/s13280-015-0644-x

Arts, B., & Buizer, M. (2009). Forests, discourses, institutions. A discursive-institutional analysis of global forest governance. *Forest Policy and Economics*, *11*(5–6), 340–347. https://doi.org/10.1016/j.forpol.2008.10.004

Ayres, L. (2008). Semi-Structured Interview. In L. Given (Ed.), *The SAGE encyclopedia of qualitative research methods* (pp. 811–812). https://doi.org/10.5860/CHOICE.46-4214

Bakker, K., & Cook, C. (2011). Water Governance in Canada: Innovation and Fragmentation. *International Journal of Water Resources Development*, *27*(2), 275–289. https://doi.org/10.1080/07900627.2011.564969

BC Hydro. (2002). *Executive Summary: Jordan River Water Use Plan Consultative Committee Report*. https://doi.org/10.1007/s00247-002-0666-y

BC Hydro. (2003). *Jordan River Water Use Plan*.

BC Hydro. (2015). *Water Use Plan Orders Review Program*. Retrieved from https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/gds14-303c-wupor-project-update-med-res.pdf

Brandes, O. M., Brooks, D., & M’Gonigle, M. (2007). Moving Water Conservation to Centre Stage. In K. Bakker (Ed.), *Eau Canada: The Future of Canada’s Water* (pp. 281–300). UBC Press.

Brandes, O. M., & O’Riordan, J. (2014). *A Blueprint for Watershed Governance in British Columbia*.

Brandes, O. M., & Simms, R. (2018). *Advancing Freshwater Protection: Tools and Opportunities in British Columbia's Water Sustainability Act*.

Burt, D. (2012). *Summary of Water Quality and Biological Data for Anadromous Reaches of the Jordan River*.

Burt, D. W. (2006). *Lower Jordan River fish index study - year 1 results (2005)*. Burnaby, BC.

Burt, D. W. (2007). *Lower Jordan River fish index study - year 2 results (2006)*. Burnaby, BC.

Burt, D. W. (2008). *Lower Jordan River fish index study - year 3 results (2007)*. Burnaby, BC.

Burt, D. W. (2009). *Lower Jordan River fish index study - year 4 results (2008)*. Burnaby, BC.

Burt, D. W. (2010). *Lower Jordan River fish index study - year 5 results (2009)*. Burnaby, BC.

Burt, D. W. (2011). *Lower Jordan River fish index study - year 6 results (2010) and pre/post flow release comparisons (DRAFT)*. Burnaby, BC.

Capital Regional District. (2014). *Shirley-Jordan River Official Community Plan ROUGH DRAFT*. Retrieved from https://www.crd.bc.ca/docs/default-source/jdf-pdf/shirley-jordan-river-ocp/pps-jdf-2014-09-01-sjr-roughdraft-2.pdf?sfvrsn=2

Cascadia Biological Services. (2006). *Jordan River spawning assessment and enumeration, Year 1 (Sept 2005 - May 2006): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2007). *Jordan River spawning assessment and enumeration, Year 2 (Sept 2006 - May 2007): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2009). *Jordan River spawning assessment and enumeration, Year 3 (Sept 2007 - May 2008): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010a). *Jordan River spawning assessment and enumeration, Year 5 (Sept 2009 - May 2010): WUP Monitor JORMON#3*. Burnaby, BC.

Cascadia Biological Services. (2010b). *No TitleJordan River spawning assessment and enumeration, Year 4 (Sept 2008 - May 2009): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Cascadia Biological Services. (2011). *Jordan River spawning assessment and enumeration, Year 6 (Sept 2010 - May 2011): WUP Monitor JORMON#3 (DRAFT)*. Burnaby, BC.

Charmaz, K. (2008). Grounded Theory. In J. Smith (Ed.), *Qualitative psychology. A practical guide to research methods.* (pp. 81–91). Thousand Oaks, CA: Sage Publications.

Curran, D. (2015). Water law as a watershed endeavour: federal inactivity as an opportunity for local initiative. *Environmental Law Practices*, *28*, 53–87.

Curran, D. (2017). Leaks in the system: Environmental flows, aborignial rights, and the modernization imperative for water law in British Columbia. *University of British Columbia Law Review*, *50*(2), 233.

Curran, D. (2019). Indigenous processes of consent: Repoliticizing water governance through legal pluralism. *Water (Switzerland)*, *11*(3). https://doi.org/10.3390/w11030571

Curran, D., & Brandes, O. M. (2017). Changing Currents: A Case Study in the Evolution of Water Law in Western Canada. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (pp. 45–68). Springer International Publishing.

Curran, D., & Mascher, S. (2016). Adaptive Management in Water Law: Evaluating Australian (New South Wales) and Canadian (British Columbia) Law Reform Initiatives. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3007790

De Loe, R., & Kreutziser, R. (2007). Challenging the Status Quo: The Evolution of Water Governance in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 85–103).

Dey, I. (2003). Qualitative data analysis: A user-friendly guide for social scientists. In *Qualitative Data Analysis: A User-Friendly Guide for Social Scientists*. https://doi.org/10.4324/9780203412497

Dunn, K. (2010). Interviewing. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography* (p. 110). Oxford University Press: Canada.

Foerster, A. (2011). Developing Purposeful and Adaptive Institutions for Effective Environmental Water Governance. *Water Resources Management*, *25*(15), 4005–4018. https://doi.org/10.1007/s11269-011-9879-x

Gibson, W., & Brown, A. (2009). *Working with Qualitative Data*. https://doi.org/10.4135/9780857029041

Gregory, R., Failing, L., & Higgins, P. (2006). Adaptive management and environmental decision making: A case study application to water use planning. *Ecological Economics*, *58*(2), 434–447. https://doi.org/10.1016/j.ecolecon.2005.07.020

Gullason, K. (2018). The Water Sustainability Act, Groundwater Regulation, and Indigenous Rights to Water: Missed Opportunities and Future Challenges. *Appeal: Review of Current Law and Law Reform*, *23*, 29.

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., … Bergsma, E. (2010). The Adaptive Capacity Wheel: A method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science and Policy*, *13*(6), 459–471. https://doi.org/10.1016/j.envsci.2010.05.006

Harding, J. (2015). *Identifying Themes and Coding Interview Data: Reflective Practice in Higher Education*. https://doi.org/10.4135/9781473942189

Hill, C., Furlong, K., Bakker, K., & Cohen, A. (2008). Harmonization versus subsidiarity in water governance: a review of water governance and legislation in the canadian provinces and territories. *Canadian Water Resources Journal*, *33*(4), 315. Retrieved from http://uvic.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMw3V1dT9swFLUYT9vDxNjGGCD5iReUKbabJkHioaAheEJooD1WqXNdVXSplLRC_Ij9Z-

61HSct6h_grY2bD8Wn9v0491zGlPwVRxtrgpSQDnUCuUliaQZgMikGWgrQOX63Cd5eNdlO21CsO_YeJv6mqPEOvrzyjFgXq-aswfVhhlCgVnUU4nguSBxxahvt0ry7mu

Hunter, R., Brandes, O. M., & Moore, M. (2014). *A Watershed Governance Case Study. The Cowichan Watershed Board : An Evolution of Collaborative Watershed Governance*.

Hydro, B. (2016). Planning to Improve Fish Habitat on Jordan River. Retrieved April 18, 2016, from Fish and Wildlife Program website: http://fwcp.ca/project/planning-to-improve-fish-habitat-on-jordan-river/

Joe, N., Bakker, K., & Harris, L. M. (2017). *Perspectives on the BC Water Sustainability Act: First nations respond to water governance reform in British Columbia*. https://doi.org/10.13140/RG.2.2.14041.31840

Johns, R., Chan, C., Gunardi, A., & Felker, A. (2014). *Treatment of Woodwaste Landfill Leachate Using Engineered Wetlands: Jordan River*. Retrieved from http://www.bceia.com/media/61764/jordanriverwetlands.pdf

Lautze, J., De Silva, S., Giordano, M., & Sanford, L. (2011). Putting the cart before the horse: Water governance and IWRM. *Natural Resources Forum*, *35*(1), 1–8. https://doi.org/10.1111/j.1477-8947.2010.01339.x

Matthews, G., & Hill, E. L. (2004). Balancing Water Use Planning at BC Hydro. *Presentation to 9th Living Lakes Conference “Land and Water Use in Recreational Development - Business and Corporate Social Responsibility for Water Ecosystems’’, Columbia River Wetlands, BC,”* Presentation.

Moore, M., & Baltutis, W. J. (2016). Assessing capacity in watershed organizations in British Columbia: A study of reliability and resilience in organizational processes. *Canadian Water Resources Journal*, *1784*(May), 1–13. https://doi.org/10.1080/07011784.2015.1137230

Morgan, D. (2008). Snowball Sampling. In L. Given (Ed.), *The SAGE encyclopedia of qualitative* *research methods* (p. 816). https://doi.org/10.5860/CHOICE.46-4214

Morris, B. T., & Brandes, O. M. (2013). *The State of the Water Movement in British Columbia: A Waterscape Scan & Needs Assessment of B.C. Watershed-Based Groups*. (July), 46. Retrieved from http://polisproject.org/files/pub_database/stateofwatermovement_lowres.pdf

Palys, T. (2008). Purposive Sampling. In L. Givens (Ed.), *The SAGE encyclopedia of qualitative research methods* (p. 698). https://doi.org/10.5860/CHOICE.46-4214

Reed, M. G., & Bruyneel, S. (2010). Rescaling environmental governance, rethinking the state: A three-dimensional review. *Progress in Human Geography*, *34*(5), 646–653. https://doi.org/10.1177/0309132509354836

Robinson, C. J., Bark, R. H., Garrick, D., & Pollino, C. A. (2015). Sustaining local values through river basin governance: community-based initiatives in Australia's Murray-Darling basin. *Journal of Environmental Planning and Management*, *58*(12), 2212–2227. https://doi.org/10.1080/09640568.2014.976699

Roulston, K., deMarrais, K., & Lewis, J. B. (2003). Learning to Interview in the Social Sciences. *Qualitative Inquiry*, *9*(4), 643–668. https://doi.org/10.1177/1077800403252736

Scodanibbio, L. (2011). Opening a policy window for organisational change and full-cost accounting: The creation of BC Hydro's water use planning program. *Ecological Economics*, *70*(5), 1006–1015. https://doi.org/10.1016/j.ecolecon.2010.12.022

Smart, A. (2014, December 12). Meeting Little Comfort for Jordan River Dam's Path. *Times Colonist*. Retrieved from https://www.timescolonist.com/news/local/meeting-little-comfort-for-jordan-river-residents-in-dam-s-path-1.1664167

*Water Sustainability Act.* SBC, (2014). c 15. http://www.bclaws.ca/civix/document/id/complete/statreg/14015

Walkem, A. (2007). The Land Is Dry: Indigenous People, Water and Environmental Justice. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 303–319). UBC Press.

Weick, K., & Sutcliffe, K. (2001). *Managing the Unexpected: Assuring High Performance in an Age of Complexity*. https://doi.org/10.1016/s0263-2373(02)00124-x

Wright, M. C., & Guimond, E. (2003). *Jordan River Pink Salmon Incubation Study*.

Yamagata, Y., Sewell, G., Wasson, M., & Young, O. (2001). Institutional Dimension of Global Environmental Change (IDGEC) Carbon Management Research Activity (CMRA) Summary report of the Tokyo workshop. *Climate Policy*. https://doi.org/10.3763/cpol.2001.0113

Yin, R. K. (2009). Case Study Research: Design and Methods. In L. Bickman & D. J. Rog (Eds.), *Essential guide to qualitative methods in organizational research*. https://doi.org/10.1097/FCH.0b013e31822dda9e

# Chapter Four: Conclusions

## Introductory Reflections

During the time that I spent working on my graduate coursework and thesis research, the water governance regime in British Columbia has evolved. There has been a greater focus on reconciliation and the recognition of applying Indigenous approaches to water challenges (Castleden, Hart, Cunsolo, Harper, & Martin, 2017; Curran, 2019). In 2014, a decision made by the Supreme Court of Canada confirms that Indigenous rights and title to land can no longer be ignored without legal implications (*Tsilhqot'in Nation v. British Columbia*, 2014). Governments and industry have a legal requirement to engage Indigenous nations in a meaningful way and obtain consent prior to resource development projects in unceded territory. Across B.C., watershed-based groups continue to emerge and generate local benefits that enhance water governance and inform watershed decision making (Fraser Basin Council, 2016; Hunter, Brandes, & Moore, 2014; Moore & Baltutis, 2016; Morris & Brandes, 2013; POLIS with Columbia Basin Trust and Living Lakes Canada, 2018). Recent policy initiatives and provincial legislation have led to initiatives that improve transparency in provinces by increasing public participation (Renzetti & Dupont, 2017). In 2016, B.C.'s *Water Sustainability Act* (*WSA*) enabled delegated watershed governance authority and planning (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017; Water Sustainability Act, 2014). The *WSA* offers immediate opportunities for growth and improvement in Canadian water governance, as the criteria for the delegation of watershed governance authority are actively being developed and tested in support with watershed user groups and rights holder (Brandes & Simms, 2018; Curran & Brandes, 2017). As an increasing number of watershed groups have emerged and in light of the opportunities within BC presented by the legislative changes at the provincial level, there is a need to better understand whether capacity exists to implement a different model for governance.

Pacific salmon has moved to the center stage of conservation efforts following strict conservation measures, predation competition and overall decline in wild stocks that have become significantly evident over the last few years (Adams et al., 2016; Chasco et al., 2017). On July 5, 2019, Fisheries and Oceans Minister, John Wilkinson, and British Columba's Minister of Agriculture, Lana Popham, announced twenty-three project proposals under the British Columbia Salmon Restoration and Innovation Fund (BCSRIF), which will offer an investment of up to $142.85 million over the next five years to fund projects that focus on protecting and restoring British Columbia's wild salmon stocks (Fisheries and Oceans Canada, 2019a). On June 21, 2019, Bill C-68, an Act to amend the *Fisheries Act* received royal assent and became law (Fisheries and Oceans Canada, 2019b). The new provisions under the modernized *Fisheries Act* provide stronger protection for all fish and fish habitat, including a focused priority on restoring fish stocks and fish habitat (Fisheries and Oceans Canada, 2019b). There has been a recent shift in federal and provincial government priorities to focus on the importance of protecting and restoring fish habitat and rebuilding wild Pacific salmon stocks. British Columbia resource extraction infrastructure, specifically abandoned mine sites, have been toxic legacies responsible for detrimental effects on wild Pacific salmon stocks (Barry, Grout, Levings, Nidle, & Piercey, 2000; SNC Lavalin, 2016; Tsolum River Restoration Society, 2016). Therefore, these numerous, ongoing efforts have, and will all continue to shape the Jordan River basin beyond the data collection period.

In this thesis, I set out how to investigate whether watershed governance capacities are present in watersheds where previous participatory planning processes have occurred, and how natural resource operations have affected freshwater quality beyond the scope of these planning processes. My thesis represents an attempt to contribute to critical conversations on the capacities of water governance in the context of watershed planning and resource extraction. This final chapter summarizes the conclusions reached in the thesis, identifies how I met my four research objectives and sets out my contribution to scholarship. The limitations are acknowledged, and recommendations are highlighted for further research investigation.

**Summary of Major Findings**

In the first chapter of the thesis, I identified gaps and challenges in the water governance literature, including the traditional approaches to water governance that focused on supply-management perspectives (Brandes, Brooks, & M'Gonigle, 2007; Sprague, 2007) and the barriers in fragmented distributions of power and authority across multiple jurisdictions (Bakker & Cook, 2011; Brandes & O'Riordan, 2014; Muldoon & McClenaghan, 2007; Renzetti & Dupont, 2017). I summarized British Columbia's history of resource extraction legacies that continue to contribute to environmental degradation long after operations have stopped (Barry et al., 2000; Hunter et al., 2014). Ecological and social concerns have not always been considered in water policy until recent history (Muldoon & McClenaghan, 2007). As a result of these conventional policy practices, communities within watersheds are unable to cope with the pressures generated by resource development and are faced with water challenges like droughts, rapid resource development, and contaminated water. The Province of British Columbia conducted the Water Use Planning (WUP) program, which was designed to revise the operating plans of BC Hydro's hydroelectric facilities in order to improve the protection of social and environmental values beyond hydro production and mitigate some of the water challenges between users and rights holders in B.C. (Scodanibbio, 2011). Often community concerns were beyond the scope of the WUPs, and some watershed communities have begun to focus on the creation of a watershed-based group as an institutional mechanism for greater influence in water governance and water management in the watershed (Hydro, 2016).Watershed-based groups are emerging across B.C. and attempting to approach collaborative and shared decision-making alongside ecological objectives (Brandes & Simms, 2018; Curran, 2017; Curran & Brandes, 2017; Moore & Baltutis, 2016). British Columbia's *WSA* has offered an opportunity to delegate select governance responsibilities to local watershed institutions (Brandes & O'Riordan, 2014; Brandes & Simms, 2018), but it is unclear which watershed-based institutions have the capacity to take on new roles and authority. Questions remain on whether these local watershed-based institutions can be evaluated at an early stage of the watershed organization being created.

Chapter two focused on addressing the research question: how have resource operations have affected freshwater quality in the Jordan River implicated in the WUP? Water quality has been identified as one of the top five water challenges in British Columbia's future (Simms & Brandes, 2016). There is often an absence of data and information about water quality in watersheds (Moore, Shaw, & Castleden, 2018), specifically information on the impacts of abandoned mine sites on water quality (Venkateswarlu et al., 2016). A document review provided information on the WUP process challenges and the relationship of those challenges to long-standing historical developments of resource extraction activities that have affected water quality and quantity (Thesis Objective #1). Spatial and seasonal water quality trends were identified through a five-week water quality study that assessed the current environmental state of the Jordan River watershed to understand the primary issues of concern in the watershed (Thesis Objective #2). The water quality analysis showed that copper is the primary contaminate affecting the productivity of a healthy salmon habitat during their spawning events during the Fall freshets in the Jordan River. The water quality data, specifically the copper analysis, showed that impacts of acid mine drainage processes were strongly influenced by existing mine waste and tailings piles that were sourced from an abandoned copper mine in combination with unnatural anthropogenic flows from the three BC Hydro dams present in the river system. The three BC Hydro reservoirs on the Jordan River system negatively affect the cycling and transport of dissolved organic carbon, which plays an essential role in balancing aquatic chemistry by combining with other metals and nutrients and buffering toxicity to freshwater aquatic life. Overall, resource operations have affected freshwater quality in the Jordan River, and these water quality concerns have led to the creation of the Jordan Watershed Round Table (JWRT), which will aid in open discussions and collaboration on rebuilding a healthy Pacific salmon habitat in Jordan River. The water quality study created in this thesis is provincially applicable, repeatable and will be useful in future-water related decisions and data collection in the Jordan River watershed.

Chapter three focused on addressing the research question: how does a watershed community address concerns in a watershed planning process, like the WUP, through developed adaptive capacity? The Jordan River community began to push towards local watershed governance by establishing the JWRT. The Jordan River watershed underwent the WUP process and, therefore, it could be hypothesized that the JWRT should have many of the “adaptive capacities” for effective water governance present. My research addressed how the WUP process has contributed to creating watershed governance capacity in the Jordan River watershed by capturing the perspectives and experiences of a diverse range of watershed actors through interviews and observational opportunities. The Gupta et al. (2010) adaptive capacity dimensions (e.g. variety, learning, room for autonomous change, leadership, resources, and aspects of fair governance) were tested using the qualitative data collected from prospective and current members of the JWRT (Thesis Objectives #3 and #4). The Gupta et al. (2010) framework proved to be a valuable tool to assess whether these watershed governance capacities were present, specifically the application of the “Adaptive Capacity Wheel”, which visually outlined areas of success and reform for the JWRT. Overall, the JWRT displayed a multiple actor, sector and level approach to addressing a diverse range of problem frames and solutions. The adaptive capacity dimension for resources was highlighted as an area that could improve, because the JWRT lacked sustainable long-term funding and dependable access to human resources that could conduct studies in the watershed. Furthermore, the JWRT does not meet the criteria of authority, and at this point in time, does not meet specific criteria for delegations under the *WSA*.

The Gupta et al. (2010) framework was effective in addressing the research question in the assessment of the JWRT, but there were some themes that emerged from the data that did not fit directly with adaptive capacity dimensions or criteria in the assessment, such as information about the historical events of the Jordan River, major gaps in governance, future solutions, salmon habitat, Indigenous knowledge, or details on specific relationships between participants (such as conflict or emotions). These themes were still valuable to the research project and were used to create a narrative that outlines key episodes, chronological sequences and define roles in the Jordan River watershed. The Gupta et al. (2010) criteria definition for "authority" under the adaptive capacity dimension of "resources" is recommended to be broadened to include the provision of accepted or legitimate forms of power under provincial/state legislation, regional or municipal delegations of authority.

Overall, the research concluded that the WUP has contributed to some adaptive capacity for watershed governance in the Jordan River, specifically on building the adaptive capacity dimensions of: variety, learning capacity, room for autonomous change, leadership, and resources. The researcher observed a variety of watershed actors participate in the JWRT including multiple levels of government agencies and sectors, including regional, provincial and federal agencies, First Nations, non-profit organizations, community members, academia and industry representatives which were reflective of the participants who were previously involved in the WUP consultative process in 2000. Five out of the fourteen members from the previous

WUP consultative committee were now involved with the JWRT seventeen years later. As a result, interests and uncertainties that were raised but not addressed during the consultative committee process of the WUP were carried over to the emerging JWRT, specifically regarding the concerns of cultural use of the watershed, salmon habitat, water quality contamination and remediation efforts. These interests were beyond the scope of the WUP and were later categorized as key problems that need to be addressed in the JWRT, especially regarding stewardship in the Jordan River watershed. Furthermore, the WUP studies are still currently active and form the base of scientific information for the JWRT.

**Limitations of the Study**

The dynamism of the water governance regime in the Jordan River watershed was an important limitation to this study. The watershed was undergoing a major transition of change during the data collection periods, as the community was actively in the process of creating and establishing the JWRT amongst community members, industry stakeholders, government agencies and Indigenous rights holders. At the same time, the Jordan River was finally receiving robust attention from the public and media in regards to JWRT participants speaking up about their concerns of the copper contamination that was suggested to be responsible for the loss of wild Pacific salmon stocks in the Jordan River (BC Local News, 2017; Davis, 2017; M. Hume, 2016; S. Hume, 2016; Lacatusu, 2016; Sequeira, 2017; Smart, 2016). Amongst the Jordan River community, there were escalated tensions with BC Hydro following an announcement of a seismic hazard assessment, the conclusion of which was the potential of a dam failure following a major earthquake that would significantly impact residents of the Jordan River waterfront community (BC Hydro, 2014). In 2016, the waterfront properties were in the process of being bought out by BC Hydro to be rezoned to restrict residential use and development, which was fracturing the relationships between the community and industry (Derosa, 2017; Hudson, 2017;

Mcelroy, 2016). The Pacheedaht First Nation was in the process of formalizing treaty negotiations, (BC Treaty Commission, 2019) which may have influenced their perspectives and responses during the data collection.

The overall temporal scope of the study was constrained within a time frame of a Master's program, and thus represents a snapshot of time that does not capture important events that have occurred most recently in the Jordan River watershed. As a result, events and changes after March 2018 were not included as a part of investigation of this research. The Detailed Site Investigation (DSI) which resulted from the ministerial order of the *Contaminated Site Regulation* was in the initial planning stages in 2017, and remedial options for the mine had not been confirmed from Teck. The Jordan River WUP was under review in 2018 and consultations with First Nations and the public were ongoing. The Jordan River WUP review was concluded and published in January 2019 (BC Hydro, 2019). An important milestone for the Pacheedaht First Nation was the signing of their Agreement in Principle with Canada and British Columbia in June 2019 (JFK Law Corporation, 2019). Furthermore, it is important that I acknowledge my positionality, as a settler who has lived and worked for most of my life within the watershed, which inevitably would contribute to shaping my analysis and interpretation of data by having a strong connection and previous history with the case study. These experiences not only construct my positionality as a researcher but make a stronger project because the research is built further on traditional knowledge, in addition to the researcher being immersed in the process of water governance during the research project and not just researching from a static position. Therefore, this thesis represents a culmination of knowledge growth, intensive learning, and professional development. Concrete measures were taken to ensure that my analysis was rigorous and factual (described in Chapter 1).

Since additional water quality analysis and interviews with industry stakeholders, community members, government agencies and Indigenous nations may have provided more information, I have made recommendations for future water quality efforts in the Jordan River, and I disclosed which members that I wanted to interview for the study that were not able to participate (described in Chapter 3). Additional water quality analyses were not financially feasible due to funding constraints. Altogether the cost of the water quality analysis for 40 samples over a five-week period of five different sites on the Jordan River totaled $4366.95. The cost of the water quality study was expensive and supported the reasoning behind the lack of water quality studies in the Jordan River watershed completed at the spatial and seasonal extent outlined in this Master's thesis. Previous water quality samples in the Jordan River watershed were taken inconsistently and exclusively, both in temporal and spatial aspects. Contrastingly, the quantitative water quality data gathered in the Jordan River watershed is expected to remain reflective of the current state in the Jordan River until remedial options have been prescribed and applied to the mine. Regardless of the temporal constraints of this research, the Jordan River watershed findings will still provide relevant insights into watershed planning and governance processes currently underway across British Columbia, Canada, and elsewhere.

## Contributions and Looking Forward

In Canada, it is inevitable that resource extraction activities are projected to continue, and watersheds will continue to be impacted by the effects of toxic legacies long after operations have stopped. It has been argued that Canada's water crisis is said not to be one of scarcity, but of *water governance* (Brandes et al., 2007; Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007; Lautze, De Silva, Giordano, & Sanford, 2011). This thesis uses both quantitative and qualitative methods in the attempt to address how the WUP process has contributed to creating watershed governance capacity. A key contribution of this research is the water quality data that was collected in the Jordan River watershed. This study concludes that resource extraction activities in the Jordan River watershed has heavily impacted freshwater quality and destroyed pre-existing fish habitat. The results demonstrate a continued trend of copper contamination above provincial limits that has very likely persisted in the Jordan River following the beginning of resource development in the watershed in the early 1900s. Resource extraction and land-use changes are projected to increase in British Columbia alongside with climate change, and it is expected that these changes will lead to altered freshwater availability, reservoir capacity, water quality and water use for future resource extraction and energy production (Cohen, Koshida, & Mortsch, 2015; Horning, Bauer, & Cohen, 2016). Water quality has been identified as one of the top five water challenges in British Columbia's future (Simms & Brandes, 2016), but there is still an absence of data and information about water quality in watersheds (Moore et al., 2018). In Canada alone, it is estimated that over 10 000 abandoned mines exist and there is limited information on the impacts of these abandoned sites on water quality (Venkateswarlu et al., 2016). The water quality data collected in the Jordan River will contribute as a baseline water quality study that is repeatable and based on provincially recognized methods and offers a future opportunity for monitoring. The findings of the data support spatial and seasonal trends specific to the Jordan River watershed and emphasize parameters of concern that should be considered in future remediation efforts.

This research has also contributed to the current movement of emerging watershed organizations that are formally supported through new regulations in British Columbia, but questions remain about the capacities of these watershed communities to sustain such a formal institution and if these watershed communities are ready to successfully implement a local watershed governance model. This research is valuable, as it presents a framework (Gupta et al.,

2010) to assess the adaptive capacities of watershed-based institutions as communities begin to shift to watershed-based governance models. The framework highlights areas for discussion and reform and serves as an effective tool for assessing the adaptive capacities of watershed-based organizations. Furthermore, this research contributes to understanding of the initial applications of the *WSA*, specifically to an emerging watershed-based group like the JWRT. The findings concluded that the JWRT was dependent on project-based funding and had not been established for a significant amount of time nor is it a legal entity. The JWRT was unable to fund positions that could deal with legal aspects of delegations of authority; therefore, the JWRT would not meet the criteria for delegation of decision-making authority under the *WSA* at the time of this study. The framework by Gupta et al. (2010) is applicable to watershed-based organizations involving similar case studies seeking local authority, policy delegations, shared decision-making and collaboration in water governance.

Related, a third contribution from this case is evidence that the First Nation participants described their experience with the *WSA*, as introducing further complications and challenges in local decision-making, specifically regarding Treaty negotiations. The First Nation participants perceived that they were very poorly engaged during the provincial process for the drafting of the *WSA*, and was implemented without addressing any of their concerns, especially regarding water rights and access in their Treaty process. This perception was widely shared by a number of nations and various Indigenous organizations, such as the Union of British Columbia Indian Chiefs (UBCIC), as can be observed in the consultation records from the *WSA* development and supporting literature (Curran, 2019; Gullason, 2018; Joe, Bakker, & Harris, 2017).

A fourth contribution of this research is the finding that the motivations of watershed-based groups are often due to concerns that are outside the scope of other watershed planning processes, such as the WUP, where the focus in this case was managing economic trade-offs between power production and improved ecological habitat within their license for operations in power production. Although watershed planning programs, like the WUP, are well funded and structured, they do not present a holistic approach to overarching watershed concerns that harmonize the various jurisdictions and scales of water governance. In general, it appears that watershed boards and roundtables are becoming a desired way to organize people within a watershed for collaboration and partnerships in water resource decisions (Brandes & O'Riordan, 2014; De Loe & Kreutziser, 2007), and this trend appears to be growing stronger in British Columbia in recent years (Moore & Baltutis, 2016; Morris & Brandes, 2013). Therefore, the WUP has contributed to building certain adaptive capacity dimensions, including variety, learning capacity, room for autonomous change, leadership, and resources, which will shape the possibilities for watershed governance in the longer term. Further, scholarship has argued that water-related decisions are not always dependent on scientific data, and that individuals may be influenced by their personal and professional experience to generate emotional responses (Wolfe, 2012). In the case of the Jordan River watershed, the researcher observed a depth of shared passion, emotion and connection to place that was inevitable amongst the participants in this study. Although the participants expressed that they based their decisions on scientific data, they also eluded to previous professional and personal experiences in their interviews. This emotion and passion expressed by the participant's on the JWRT could not be accurately captured in the researchers notes, transcripts or framework of this study. The researcher does not doubt that decisions amongst the participants of the JWRT were influenced by this emotion and passion which was consistent throughout the study.

Finally, this research contributes to supporting change in the Jordan River watershed by highlighting areas for improvement within the JWRT and by providing an updated water quality analysis, that has been sought after by participants in this study and others in the basin. Overall, the partnerships, relationships, and experiences that have resulted from this thesis research has offered the researcher a valuable opportunity to observe a unique situation that is often overlooked as a watershed-based organization unfolds and becomes potentially established into a more formal water governance regime. The lessons learned from this case are applicable elsewhere in Canada and beyond, in watersheds with multiple resource extraction operations, watershed planning and water governance initiatives.

**Chapter Four References**

Adams, J., Kaplan, I. C., Chasco, B., Marshall, K. N., Acevedo-Gutiérrez, A., & Ward, E. J. (2016). A century of Chinook salmon consumption by marine mammal predators in the Northeast Pacific Ocean. *Ecological Informatics*, *34*, 44–51. https://doi.org/10.1016/j.ecoinf.2016.04.010

Bakker, K., & Cook, C. (2011). Water Governance in Canada: Innovation and Fragmentation. *International Journal of Water Resources Development*, *27*(2), 275–289. https://doi.org/10.1080/07900627.2011.564969

Barry, K. L., Grout, J. A., Levings, C. D., Nidle, B. H., & Piercey, G. E. (2000). Impacts of acid mine drainage on juvenile salmonids in an estuary near Britannia Beach in Howe Sound, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(10), 2032–2043. https://doi.org/10.1139/f00-157

BC Hydro. (2014). *Seismic Hazard Assessment Backgrounder*.

BC Hydro. (2019). *Jordan River Water Use Plan Order Review Report*. Retrieved from https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/vancouver-island/Jordan-River-WUPOR-Report.pdf

BC Local News. (2017, October 19). Jordan River Coming Back from the Dead: Roundtable working to restore salmon stocks. *BC Local News*.

BC Treaty Commission. (2019). *Pacheedaht First Nation*. Retrieved from http://www.bctreaty.ca/pacheedaht-first-nation

Brandes, O. M., Brooks, D., & M’Gonigle, M. (2007). Moving Water Conservation to Centre Stage. In K. Bakker (Ed.), *Eau Canada: The Future of Canada’s Water* (pp. 281–300). UBC Press.

Brandes, O. M., & O'Riordan, J. (2014). *A Blueprint for Watershed Governance in British Columbia*.

Brandes, O. M., & Simms, R. (2018). *Advancing Freshwater Protection: Tools and Opportunities in British Columbia's Water Sustainability Act*.

Castleden, H., Hart, C., Cunsolo, A., Harper, S., & Martin, D. (2017). Reconciliation and Relationality in Water Research and Management in Canada: Implementing Indigenous Ontologies, Epistemologies, and Methodologies. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (17th ed., pp. 69–99). Springer International Publishing.

Chasco, B., Kaplan, I. C., Thomas, A., Acevedo-Gutiérrez, A., Noren, D., Ford, M. J., … Ward, E. J. (2017). Estimates of chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970 to 2015. *Canadian Journal of Fisheries and Aquatic Sciences*, *74*(8), 1173–1194. https://doi.org/10.1139/cjfas-2016-0203

Cohen, S., Koshida, G., & Mortsch, L. (2015). Climate and water availability indicators in Canada: Challenges and a way forward. Part III – Future scenarios. *Canadian Water Resources Journal*, *40*(2), 160–172. https://doi.org/10.1080/07011784.2015.1006021

Curran, D. (2017). Leaks in the system: Environmental flows, aborignial rights, and the modernization imperative for water law in British Columbia. *University of British Columbia Law Review*, *50*(2), 233.

Curran, D. (2019). Indigenous processes of consent: Repoliticizing water governance through legal pluralism. *Water (Switzerland)*, *11*(3). https://doi.org/10.3390/w11030571

Curran, D., & Brandes, O. M. (2017). Changing Currents: A Case Study in the Evolution of Water Law in Western Canada. In S. Renzetti & D. P. Dupont (Eds.), *Water Policy and Governance in Canada* (pp. 45–68). Springer International Publishing.

Davis, T. (2017). Jordan River Restoration: Bringing Back the Habitat. *BC Outdoors*.

De Loe, R., & Kreutziser, R. (2007). Challenging the Status Quo: The Evolution of Water Governance in Canada. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 85–103).

Derosa, K. (2017, March 10). The last man in Jordan River. *Vancouver Sun*.

Fisheries and Oceans Canada. (2019a). *Government of Canada and Province of British Columbia Announce Salmon Restoration and Innovation Fund Projects*. Retrieved from https://www.canada.ca/en/fisheries-oceans/news/2019/07/government-of-canada-and-province-of-british-columbia-announce-salmon-restoration-and-innovation-fund-projects.html

Fisheries and Oceans Canada. (2019b). *Introducing Canada's Modernized Fisheries Act*.

Fraser Basin Council. (2016). *Advancing Sustainability Solutions Throughout British Columbia: Strategic Plan 2016-2021*. Retrieved from https://www.fraserbasin.bc.ca/_Library/About_Us/2016-21_strategic_plan.pdf

Gullason, K. (2018). The Water Sustainability Act, Groundwater Regulation, and Indigenous Rights to Water: Missed Opportunities and Future Challenges. *Appeal: Review of Current Law and Law Reform*, *23*, 29.

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., … Bergsma, E. (2010). The Adaptive Capacity Wheel: A method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environmental Science and Policy*, *13*(6), 459–471. https://doi.org/10.1016/j.envsci.2010.05.006

Horning, D., Bauer, B. O., & Cohen, S. J. (2016). Missing bridges: Social network (dis)connectivity in water governance. *Utilities Policy*, *43*, 59–70. https://doi.org/10.1016/j.jup.2016.06.006

Hudson, K. (2017, February 28). Only Cabin Owner Left in Jordan River, B.C. Vows to Stay. *CBC News*. Retrieved from https://www.cbc.ca/news/canada/british-columbia/jordan-riversole-resident-left-1.4003196

Hume, M. (2016, October 16). The Rebirth of B.C.'s Jordan River is a Victory for Biological Activism: Polluted and long given up for dead, a water body on Vancouver Island provides optimism and a model for streams across the province. *The Globe and Mail*.

Hume, S. (2016, October 4). Jordan River Salmon Wiped Out by Copper Tailings. *Vancouver Sun*. Retrieved from https://vancouversun.com/opinion/columnists/jordan-river-salmon-wiped-out-by-copper-tailings

Hunter, R., Brandes, O. M., & Moore, M. (2014). *A Watershed Governance Case Study. The Cowichan Watershed Board : An Evolution of Collaborative Watershed Governance*.

Hydro, B. (2016). Planning to Improve Fish Habitat on Jordan River. Retrieved April 18, 2016, from Fish and Wildlife Program website: http://fwcp.ca/project/planning-to-improve-fish-habitat-on-jordan-river/

JFK Law Corporation. (2019). *Ditidaht and Pacheedaht First Nations Sign Agreement in Principle in BC Treaty Process*. JFK News.

Joe, N., Bakker, K., & Harris, L. M. (2017). *Perspectives on the BC Water Sustainability Act: First nations respond to water governance reform in British Columbia*. https://doi.org/10.13140/RG.2.2.14041.31840

Lacatusu, O. (2016, October 8). Student Predicts Jordan River Can Be Saved: Salmon spawning ground decimayed by copper mine tailings. *Sooke News Mirror*.

Lautze, J., De Silva, S., Giordano, M., & Sanford, L. (2011). Putting the cart before the horse: Water governance and IWRM. *Natural Resources Forum*, *35*(1), 1–8. https://doi.org/10.1111/j.1477-8947.2010.01339.x

Mcelroy, J. (2016, August 5). Jordan River Residents Say They Don't Want to Sell to BC Hydro. *Global News*.

Moore, M.-L., & Baltutis, J. (2016). Assessing capacity in watershed organizations in British Columbia: A study of reliability and resilience in organizational processes. *Canadian Water Resources Journal*, *1784*(May), 1–13. https://doi.org/10.1080/07011784.2015.1137230

Moore, M.-L., Shaw, K., & Castleden, H. (2018). We Need More Data! *Water Alternatives*, *11*(1), 142–162. Retrieved from https://poliswaterproject.org/files/2018/02/Art11-1-8.pdf

Morris, B. T., & Brandes, O. M. (2013). *The State of the Water Movement in British Columbia: A Waterscape Scan & Needs Assessment of B.C. Watershed-Based Groups*. (July), 46. Retrieved from http://polisproject.org/files/pub_database/stateofwatermovement_lowres.pdf

Muldoon, P., & McClenaghan, T. (2007). A Tangled Web: Reworking Canada's Water Laws. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 245–261). UBC Press.

POLIS with Columbia Basin Trust and Living Lakes Canada. (2018). *Community Engagement in Watershed Governance : Case Studies and Insights from the Upper Columbia River Basin*. University of Victoria, BC.

Renzetti, S., & Dupont, D. P. (2017). *Water Policy and Governance in Canada*. https://doi.org/10.1007/978-3-319-42806-2

Scodanibbio, L. (2011). Opening a policy window for organisational change and full-cost accounting: The creation of BC Hydro's water use planning program. *Ecological Economics*, *70*(5), 1006–1015. https://doi.org/10.1016/j.ecolecon.2010.12.022

Sequeira, N. (2017). *The Jordan River Watershed Project*. Retrieved from https://ecologyst.com/blogs/news/the-jordan-river-watershed-project

Simms, R., & Brandes, O. M. (2016). Top 5 water challenges that will define British Columbia's future. In *POLIS Project on Ecological Governance, Centre for Global Studies, University of Victoria*. Retrieved from http://poliswaterproject.org/sites/default/files/POLIS-Top5-final-web-v2.pdf

Smart, A. (2016, October 4). One Man's Quest to Restore Jordan River Salmon; Water Fouled by Old Mine. *Times Colonist*.

SNC Lavalin. (2016). *Supplemental Stage 1 and Limited Stage 2 Preliminary Site Investigation and Preliminary Risk Opinion - Sunro Mine, Jordan River, BC*.

Sprague, J. (2007). Great Wet North? Canada's Myth of Water Abundance. In K. Bakker (Ed.), *Eau Canada: The Future of Canada's Water* (pp. 23–35). UBC Press.

*Tsilhqot'in Nation v. British Columbia*. SCC 44, (2014).

Tsolum River Restoration Society. (2016). *Tsolum River Recovery Plan: Tsolum River Watershed*. Retrieved from https://www.tsolumriver.org/uploads/4/0/5/7/4057952/tsolum_river_recovery_plan-vaug2016.pdf

Venkateswarlu, K., Nirola, R., Kuppusamy, S., Thavamani, P., Naidu, R., & Megharaj, M. (2016). Abandoned metalliferous mines: ecological impacts and potential approaches for reclamation. *Reviews in Environmental Science and Biotechnology*, *15*(2), 327–354. https://doi.org/10.1007/s11157-016-9398-6

*Water Sustainability Act*. SBC, (2014). c 15 http://www.bclaws.ca/civix/document/id/complete/statreg/14015

Wolfe, S. E. (2012). Water Cognition and Cognitive Affective Mapping: Identifying Priority Clusters Within a Canadian Water Efficiency Community. Water Resources Management. https://doi.org/10.1007/s11269-012-0061-x