ASSESSING THE LIMITING FACTORS FOR RE-INTRODUCTION OF SOCKEYE SALMON TO THE COQUITLAM WATER SUPPLY AREA

By

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We accept this thesis as conforming
to the required standard

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ABSTRACT

Prior to the construction of the dams, migrating salmonid species accessed the upper reaches of the Capilano, Seymour, and Coquitlam watersheds as an integral part of their natural lifecycle. There are multiple initiatives being undertaken by BC Hydro and the stakeholders to re-introduce sockeye salmon (*Oncorhynchus nerka*) to one of their natural habitat in the upper Coquitlam watershed. Concerns have been raised that the restoration may be in conflict with the drinking water mandate of Metro Vancouver's watershed management policies. The research objective of this project was to investigate and assess the social, economic, and environmental aspects of restoring an extirpated sockeye salmon population. Through an exploratory case-study approach, the research concluded that the existing fish passage constraints and reliance upon re-anadromy to restore the population are limiting factors in sustaining the Coquitlam Reservoir sockeye.

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BCRP – Bridge Coastal Restoration Program

BCUC – British Columbia Utilities Corporation

CWSA – Coquitlam Water Supply Area

GWH – Gigawatt hour

GVRD – Greater Vancouver Regional District

GVWD – Greater Vancouver Water District

HCP – Habitat Conservation Plan

KSRP – Kwikwetlem Salmon Restoration Program

LLO – Low level outlet

MV – Metro Vancouver

PCB – Polychlorinated biphenyl

PSE – Puget Sound Energy

SPU - Seattle Public Utilities

SRI – Sustainable Region Initiative

WCED – World Commission on Environment and Development

WSP – Wild Salmon Policy

WUP – Water Use Plan

CHAPTER ONE: INTRODUCTION

Metro Vancouver (MV) manages three community-based watersheds, which supply drinking water to 2.3 million residents of British Columbia’s lower mainland. Prior to the construction of the dams, migrating salmonid species accessed the upper reaches of the Capilano, Seymour, and Coquitlam watersheds as an integral part of their natural lifecycle. The disruption in the salmonid natural lifecycle has resulted in diminishing annual returns of spawning adults to MV’s three water supply areas. A concerted effort to re-introduce sockeye salmon above the dam to the upper Coquitlam Watershed (See Figure 1; Appendix A) by BC Hydro, the Kwikwetlem First Nation, various levels of government including the Department of Fisheries and Oceans, and environmentally-based community organizations has started as a means of restoring migrating salmonid species.

In potential conflict with these efforts for salmonid re-introduction are the economic benefits that MV receives through the use of an impounded reservoir for domestic water supply purposes. In addition, MV’s current drinking water standards of quality may be compromised resulting in further costly water treatment options being considered.

For the past century, the reservoir has also provided power generating revenue to BC Hydro. Past actions concerning the construction of the dam may place the utility as ultimately responsible for the extirpation of anadromous salmonid species in the Coquitlam Water Supply Area (CWSA).

Background

The CWSA is approximately 20,000 hectares in size and lies immediately northeast of Vancouver, British Columbia. Coquitlam Lake, a natural water body was 900 hectares in size prior to the construction of the dam and increased to a 1,200-hectare reservoir through the flooding of additional valley bottom by 1914 (See Figure 2). The watershed likely supported habitat for most species of Pacific salmon (*Oncorhynchus spp.*) prior to the early 1900s and the reservoir currently supports kokanee, cutthroat trout, rainbow trout, peamouth chub, northern pike minnow, and largescale sucker (Bocking and Gaboury, 2003).

Figure 2: Photo of the Coquitlam Dam, Reservoir and CWSA (Source: BC Hydro, 2008).

Hydrology

Steeply forested slopes within the Pacific Range of the Coast Mountains characterize the Coquitlam watershed. Runoff is generated by rain, snowmelt, and rain-on-snow events. Maximum daily discharge usually occurs in the fall or early winter, typically as a result of rain-on-snow events. The greatest monthly inflows to the reservoir occur in May and June and are a result of melting snow pack in the mid-to-upper elevations. Drought years are relatively infrequent but have the potential to impact domestic water supply, power generation, and downstream fisheries values.

A Water Survey of Canada gauging station on the Coquitlam River above the reservoir suggests a mean annual flow of 6.34 m^3/sec with an associated mean annual runoff of 3,655 mm (Acres International Limited, 1997). The water supply from the ultra-oligotrophic Coquitlam Reservoir is known for its high quality and generally has the lowest turbidity readings of the three MV sources. The limnological characteristics of the reservoir include low nutrient concentrations, low phytoplankton biomass, and good water clarity (Bussanich, Bocking, Field, Nordin, Banner-Martin, Perga, & Mazumder, 2006). Fish production in the reservoir may be limited however, due to low zooplankton stocks compared to other oligotrophic lakes on the west coast (Bussanich et al., 2006).

First Nations History

"The Coquitlam watershed forms the core territory of the Kwikwetlem First Nation, a people whose history is tied closely to the natural resources and landscape of the watershed" (Oakes & Brown, 2007, p. 7). According to Koop (2001), the very name Kwikwetlem is derived from the early-spawning sockeye salmon that utilized Coquitlam Lake prior to the construction of the dam. A number of

> other First Nations including the Tsleil-Waututh, Katzie, Musquem, Tsawwassen also hold territorial interests in various parts of the watershed due to their wide ranging traditional activities (hunting, plant collection, spiritual quests) as well as cultural and familial links to the area. (Oakes & Brown, 2007, p. 7)

While the Kwikwetlem First Nation is not currently participating in the BC Treaty Process they are actively working with BC Hydro and MV concerning issues of interest within their traditional territories. For many years now, they have been a strong advocate in restoring salmon to the CWSA.

Power Generation

Power is generated at two hydroelectric facilities on Indian Arm by the inter-basin diversion of water from Coquitlam Reservoir to Buntzen Lake Reservoir through a 3.2 km tunnel. Prior to the latest Water Use Plan (WUP), the Coquitlam / Buntzen facility historically produced 125 GWh of power. While the generation of power from this facility supplies 7% of the regional electricity demand, it only represents 0.4 % of BC Hydro's total power production in the province of British Columbia (Harris, Hardstone, & Trousdale, 2002).

BC Hydro owns several small parcels of land within the Coquitlam watershed at the locations of its primary operations, the Coquitlam Dam, and the Buntzen Tunnel Intake. BC Hydro controls the operation of the Dam, Reservoir, and Tunnel and is responsible for maintaining minimum discharges into the lower Coquitlam River. While reservoir operations and downstream releases are handled under the terms of the WUP, fish passage is considered a footprint issue and is handled separately through BC Hydro's Bridge Coastal Restoration Program (BCRP) compensation (Harris et al., 2002).

Water Supply

The City of New Westminster began utilizing Coquitlam Lake as a source of drinking water supply prior to 1903. The City of New Westminster relinquished control to the CWSA after the early 1930's when it joined the Greater Vancouver Water District

(GVWD). The GVWD is amalgamated under the Greater Vancouver Regional District which was renamed MV in 2007. Metro Vancouver currently supplies, on average, 1.1 billion litres of treated water to the residents of the Lower Mainland on a daily basis. There are no plans to add filtration to the Coquitlam Water Treatment facilities in the foreseeable future, although an ultraviolet facility is to be operational after 2012 (T. Jivraj, personal communication, January 25, 2010). Currently, this source supplies only 20% of the regions water demands, however this amount is expected to increase over the mid-term projection with a growing population and ongoing development in the eastern municipalities. With a projected population of 4 million inhabitants in the lower mainland by 2040, maintaining adequate water supplies for power generation, drinking water, and fish will be a challenge.

Metro Vancouver owns a small portion of land that is tied to water treatment and gatehouse facilities below the existing dam. The remainder of the land, well over 19,000 hectares, is leased by the GVWD from the Province of BC for the primary purpose of supplying drinking water to its member municipalities. Metro Vancouver maintains a restricted public access policy for all its watershed lands.

Governance

BC Hydro is a provincial Crown Corporation which operates one of the largest electrical utilities in Canada. The BC Government provides guidance through a number of policy initiatives which include a Shareholder’s Letter of Expectations, and the 2002 and 2007 BC Energy Plans (BC Hydro, 2009). The British Columbia Utilities Commission (BCUC) regulates BC Hydro and ensures customers get electricity in a safe, reliable, and non-discriminatory manner. BC Hydro, through its Bridge Coastal

Restoration Program (BCRP), is the sole contributor to the restoration efforts that are currently underway although MV is contributing financially to the ongoing water quality studies.

Metro Vancouver is a regional government that is comprised of 21 municipalities, one First Nation, and one electoral area. MV manages water supply, regional parks, solid and liquid waste, air quality monitoring, and subsidised housing for its member municipalities. It has regulatory powers through the province of British Columbia and collects taxes through property assessments. Various committees and a Board of Directors that is comprised of elected mayors and councillors from the lower mainland provide direction to the various programs at the regional level. All matters concerning the restoration of the sockeye to the Coquitlam Reservoir are handled through the Water and Environment Committees, and if required approval from the Board. MV has provided written support to BCRP for the fish restoration efforts that are currently underway in the CWSA.

The Re-introduction Challenge

If the re-introduction of salmonid species to their historical habitat within the watershed is to succeed, an understanding of the required steps to be taken must be defined in relationship to sustainability. Using the World Commission on Environment and Development (WCED) definition, "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. A/42/427) as the measure of a successful compromise between drinking water quality and salmon habitat requirements, the construction of the Coquitlam Dam in 1914 does not meet the WCED criteria for sustainable development as it excludes the interests of future generations. The restoration of the sockeye to the CWSA would more closely adhere to the aspect of this definition that refers to benefits of future generations, if it can be undertaken to meet the requirements for both drinking water quality and enhancement of the salmonid species migrating to this area.

BC Hydro, through BCRP, has a goal to restore as much as practicable, fish and wildlife populations that have been adversely impacted by the construction of hydroelectric facilities (BCRP, 2008). MV is currently undertaking similar fish restoration strategies for the Capilano and Seymour watersheds. Under its Sustainable Region Initiative, three operating principles, one of which is “to protect, restore and enhance natural ecosystems; exercise extraordinary care with ecosystems that contain species which are rare or endangered or are critical to living systems” have been identified (MV, 2008, p. 15). These initiatives are intended to build public confidence through the utilities’ commitment to restoring and sustaining previously extirpated species.

Starting in 2005, a spring release of water through the Coquitlam Dam facilitated the outward migration of 1,500 land-locked kokanee smolts from the drinking water reservoir above the dam. In 2007, two adult sockeye salmon that were subsequently genetically matched to the Coquitlam kokanee populations returned to the base of the Coquitlam Dam (Balcke, 2009). The adults were trapped and transported to the Coquitlam Reservoir to complete their natural life cycle.

Social Realm

The social value of restoring a salmon run is a qualitative issue that can be difficult to measure. The Kwikwetlem First Nation may attain a culturally significant milestone through a successful salmonid restoration process that involves their traditional territories. A restored food fishery with significant spiritual and cultural value may have a benefit for both native and non-native peoples. There is the potential for tourism and sport fishing opportunities with a successful restoration effort. The intrinsic value of a salmon restoration program may have environmental benefits in addition to the described anthropocentric advantages.

Environmental Realm

There are a number of environmental advantages that could be realized within the CWSA by restoring the ecosystem towards a pre-dam construction state through the re-introduction of sockeye. The environmental benefits of re-introducing salmon from an overall ecosystem perspective include the restoration of species richness and abundance. The addition of salmon carcasses to the reservoir will provide high quality organic matter and nutrients to the ecosystem food web which are currently unavailable. Such additions could benefit both the aquatic and terrestrial ecosystems. Additionally, the successful restoration of sockeye may set precedence for the natural re-introduction of coho salmon and cutthroat trout, which also likely utilized the upper reaches of the watershed.

Economic Realm

The sockeye restoration has the potential to negatively impact the generation of electricity through operating period restrictions for out-migration purposes as well as increasing fisheries outflow release as a result of the 2003 Coquitlam-Buntzen Water Use Plan (WUP). These proposed strategies to accommodate fish may cost BC Hydro revenue in the form of lost power generation in addition to ongoing operational funding.

Managing sustainable fisheries values could impact the availability of domestic water supply to MV during an extended period of drought, especially when a fish first approach has consensus agreement under terms and conditions of the 2003 Coquitlam-Buntzen WUP (Hardstone & Trousdale, 2003). This fish first approach ensures water release for the downstream aquatic ecosystem ahead of the needs of humans if supply is limited during an extended period of drought.

MV has also raised a number of concerns regarding the re-introduction of fish pertaining to potential water quality, treatment and distributional impacts. MV is risk averse concerning its water supply and needs strong evidence that restoration efforts will not compromise drinking water quality. Under its 2002 Watershed Management Plan, MV has stated that the overall goal in the plan is “Watersheds that provide clean safe water and are managed and protected as natural assets of the highest importance to the Greater Vancouver region” (Greater Vancouver Regional District [GVRD], 2002, p. 2). Currently there is no filtration in place for Coquitlam and the existing water treatment is strictly limited to ozonation and chlorination.

There are numerous cost-benefits associated with the proposed salmon restoration that warrant further investigation. This research has assessed the sustainability of re-introducing sockeye salmon to the CWSA through analyzing the social, economic, and environmental cost-benefits of salmon re-introduction in a drinking water and hydro power generating system that has been impassable to migrating fish for the past century. A number of potential limiting factors, which may preclude the sustainable restoration of salmon over the long term, have been identified and assessed. Within the scope of this study it will be determined if the successful restoration of a sockeye salmon population in the CWSA can be complimentary to the sustainable provision of high quality drinking water and power supply throughout the region.

Therefore, my research question was:

To what extent do existing fish passage constraints and potential water quality impacts to the domestic water supply limit the sustainability of re-introducing sockeye salmon to the Coquitlam Water Supply Area?

This research has the potential to aid in MV's decision-making process for the sustainable re-introduction of sockeye salmon to the Coquitlam Water Supply Area. It may also assist with decision-making regarding the MV salmonid restoration efforts underway in the Capilano and Seymour watersheds.

CHAPTER TWO: LITERATURE REVIEW

The restoration of sockeye to the Coquitlam Water Supply Area has the potential to be socially supported, economically beneficial, and environmentally advantageous provided existing fish passage constraints and potential water quality impacts can be evaluated and addressed. In this chapter, I have provided a comprehensive review, assessment, and evaluation of historic and current literature related to my research question.

Sockeye Salmon

Natural History

Sockeye salmon are one of seven species of Pacific salmon. Historically they are the third most abundant species after pink (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) (Burgner, 1991). While sockeye salmon are primarily anadromous, meaning they spend time in the ocean environment but return to their natal rivers to complete their life cycle, there are distinct populations known as kokanee that spend their entire life cycle in fresh water without going to sea (Burgner, 1991). Some kokanee also have the unique ability to re-anadromize when given the chance to out-migrate from a previously impassable system. In other lake systems, it is documented that anadromous sockeye have originated from ocean-bound kokanee (Bussanich, Bocking, Nelson, & Wood, 2006). Genetic testing has recently confirmed the relationship of Coquitlam Reservoir kokanee to the sockeye spawners that have returned to the base of the dam starting in 2007.

After emergence from the gravel, sockeye typically spend one to three years in the lake environment before migrating to the ocean. In the ocean phase of their life cycle, the fish generally spend from one to four years at sea and return to spawn and die during the summer and early fall. The Coquitlam sockeye are considered early run because they return to the river in early summer. During the spawning process their bodies turn an unmistakeable bright red with green heads. Sockeye salmon of the Fraser Basin clearly spawn on a four-year cyclic pattern (Fraser Basin Council, 2006). The Fraser, which possesses considerable lake areas accessible to salmon, is one of the two largest spawning complexes for sockeye on the entire North Pacific Rim (Burgner, 1991). While the Coquitlam Reservoir is less than 30 river km from the ocean, some sockeye migrate thousands of kilometres to reach the ocean environment and return to their natal rivers. Sockeye are unique in that they utilize lake environments for spawning and rearing which sets them apart from other salmon species (Burgner, 1991).

"Healthy fish populations depend upon habitat connectivity, on suitable habitat features which differ between species and life stages, and on river flow regimes which provide sediment, groundwater and nutrient circulation that sustain ecological integrity" (Katopodis, 2005, p. 451). The Coquitlam sockeye became locally extirpated when the newly constructed dam prevented access to the lake which had historically supported the population. First Nations were impacted when the Coquitlam sockeye could no longer return to the lake to complete their migratory life cycle.

Significance to the Kwikwetlem First Nation

Salmon have played an important role in British Columbia's First Nation societies from a food fishery and cultural perspective for several thousand years. The Kwikwetlem First Nation has strong traditional and spiritual bonds to Coquitlam Lake and its watershed, and have been advocates for responsible natural and cultural resource management within their traditional territories (Oakes & Brown, 2007). Through a letter sent by Kwikwetlem Chief Johnny to the Federal Inspector of Fisheries John McNab in 1899, the importance of the Coquitlam Lake sockeye to the Kwikwetlem First Nation is articulated:

> It will be hard for the Indians to live here if they stop our fishing. Since we were born at Coquitlam we have been living on salmon. If our fishing is stopped we can't live because we live by fishing. For a good many years fish have been breeding here and if they spoil it they take our food from us. I heard that they want to dam it and turn it into pipes that will stop the salmon from hatching here. We are all loyal subjects of the Queen and would like to be given a chance to live honestly and comfortably. If the Creek is taken away from us it will be very hard for us. It is like man taken (sic) the food out of my cupboard – the creek is our store house. (Chief Johnny, Johnny to J. McNab, March 21, 1899)

The social value of restoring a salmon run is a qualitative issue that can be difficult to measure and impartially assess. The Kwikwetlem First Nation would benefit greatly from restoring the once vibrant run of sockeye salmon to their traditional territories. A restored food fishery with significant spiritual and cultural value would benefit native and non-native peoples alike.

Modern-Day Use and Impacts

For the past 150 years, the commercial salmon fishery has been an important economic activity within the Province of British Columbia. The total commercial salmon catch in 2004 was estimated at $364 million (McRae & Pearse, 2004). At that time, First Nations salmon fisheries represented 14 % of the total catch. Since peaking in the early

1990's at 84 million fish, sockeye returns have shown a downward trend to approximately 8 million in 2004. In recent years, the commercial catches have been sporadic and difficult to project.

Diminishing salmon runs over the past several decades have been attributed to the destruction of habitat, overfishing, and climate change amongst numerous other factors (Fraser, 2001). Over the past 30 years, there has been a substantial effort expended in the restoration of the salmon resource. These efforts reflect the cultural and economic importance of the salmon to all British Columbians (Nelitz, Wieckowski, Pickard, Pawley, & Marmorek, 2007). Many initiatives have resulted in limited success with some runs still at risk or even going extinct (Fraser, 2001). In the opinion of Rosenau and Angelo (2001), there is a common lack of political will in government to protect habitat or restore conditions which would enable the recovery of the salmon populations. New policy initiatives that support wild salmon populations and their habitats are required.

Fisheries Management Issues

Sustaining wild salmon within a human-altered system is challenging from a resource manager's perspective due to the complexity and uncertainty of the issues involved. According to Lackey (Lackey, Lach, & Duncan, 2006), fisheries managers have a poor track record for ecological forecasting in the management of Pacific salmon and this has been exemplified by the recent re-forecast of the 2009 Fraser River sockeye returns which showed precipitous declines.

Historically, Pacific salmon populations have responded to changes in climate and have shown susceptibility to the associated impacts to the lake, river and ocean environments (Nelitz et al., 2007). Such impacts may include the intensity and duration of winter storms and resulting flow regimes, declining snow pack, and warmer water temperatures (Nelitz et al., 2007). Considering most salmon spend the majority of their lives at sea, they are also susceptible to changing ocean conditions which may detrimentally impact their survival (Lackey et al., 2006). Climate change issues present additional management challenges to sustaining wild populations of salmon but are not specifically investigated within the scope of this research.

Wild Salmon Policy

The 2005 federal Wild Salmon Policy (WSP) is one of the main regulatory frameworks through which genetically distinct wild salmon populations can be protected and restored in B.C. (Nelitz, Murray, & Wieckowski, 2008). The primary goal of the WSP is to restore and maintain healthy and diverse salmon populations and their habitats (Department of Fisheries and Oceans [DFO], 2005). In order to sustain wild salmon in B.C., strategies are required in which stewardship decisions consider the social, economic and biological consequences involved. The policy further states that the conservation of wild salmon is of the highest priority for the decision making in resource management and one that must honour Canada’s obligations to its First Nations (DFO, 2005).

Implications of Restoring the Coquitlam Sockeye Salmon

The restoration of the Coquitlam Reservoir sockeye has the ability to provide benefits and impacts to a system that has not seen anadromous salmonids since the early 1900s. While there are numerous benefits in restoring salmon to the CWSA, a number of potential impacts must also be considered. A number of case studies are presented to support the assessment of potential water quality impacts and fish passage strategies that were utilized to overcome anthropocentric barriers.

Overview of Potential Major Impacts and Benefits

There are five major pathways that have been identified to which the re-introduction of salmon has the potential to change or impact the quality of water withdrawn from the Coquitlam Reservoir (Perrin, Hall, Marmorek, Nelitz, & Troffe, 2007). The major pathways are:

1. Nutrient loading and algae;
2. Pathogens from fish and wildlife;
3. Contaminants from fish;
4. Disinfection by-products and taste and odour; and
5. Turbidity.

CH2M HILL in their report to the Seattle Water Department identified potential drinking water quality impacts from the proposed salmon re-introduction above the Landsburg Dam, which diverts water to a drinking water intake and treatment facilities on Cedar River. Through the decomposition of their carcasses, salmon cause potential primary, secondary, and tertiary impacts (Manning, Smith, & Olson, 1996). Primary impacts include increases in organic material and nutrients from the carcasses. Secondary impacts involve increases in pathogens as a result of wildlife feeding on salmon within the stream systems and an associated increase in fecal coliform. Additionally, increased algae growth may be encountered due to a rise in phosphorous loading from the decomposition of carcasses. Tertiary impacts include an increase in taste and odour problems in the reservoir. In Seattle's water system "taste and odour is (sic) an existing problem that is attributed to the growth of periphytic blue-green algae in the reservoir" (Manning et al., 1996, p. 4). It is suggested that additional tertiary impacts from increased algal production may affect "either quality sensitive industrial customers or a future filtration treatment plant" (Manning et al., 1996, p. 4). Moreover, increased organics and nutrients have the potential to increase biological re-growth in the distribution system and a rise in the formation of disinfection by-products which could pose a public health hazard.

If it is determined that impacts to drinking water from salmon re-introductions are real, mitigation may be required. Such strategies may include reducing the number of salmon to the reservoir or possibly considering additional water treatment such as filtration. The construction cost and ongoing operation of a water filtration plant for Coquitlam may be cost prohibitive based on the recent construction of the Seymour / Capilano Filtration plant costing the regional government in excess of $600 million.

Bocking and Gaboury (2003) indicated that the re-introduction in Coquitlam will have known but also undeterminable effects on fish species abundance in the reservoir and would probably result in a decrease in kokanee populations with their possible extirpation over time. It is thought the impacts to cutthroat and rainbow trout could be minimal. At this time, information regarding the effects of re-introduction on other resident fish populations is unavailable but the authors suggest baseline data collection and further study is required.

Activities that reduce the availability of or access to salmon may have detrimental effects on wildlife populations and potentially on ecosystem level processes (Hilderbrand, Farley, Schwartz, & Robbins, 2004). Anadromous salmon have been identified as keystone species in some ecosystems for the integral role they play in supporting vertebrate species (Willson & Halupka, 1995). Large amounts of high-quality organic matter are returned to freshwaters by spawning salmon through their eggs and the decomposition of their carcasses (Gresh, Lichatowich, & Schoonmaker, 2000). This organic detritus can be utilized by biota through direct feeding on carcasses and eggs or via uptake through decomposition by algae and bacteria. (Bilby, Fransen, Bisson, & Walker, 1998). The spawning and death of returning salmon may also influence the productivity of oligotrophic freshwaters (Johnston, MacIssac, Tschaplinski, & Hall, 2004). The Coquitlam Reservoir has been described as an ultra-oligotrophic source which suggests it is nutrient limiting. Carbon, nitrogen, and phosphorous are naturally occurring elements, which are required for growth and reproduction in all forms of aquatic life. When phosphorous and nitrogen are limiting, decomposition rates are slow and algal growth is limited.

Anders and Ashley (2007) have suggested that oligotrophication which can be attributed to dam construction, habitat alteration, acidification, and declines of salmon derived nutrients, has rendered many aquatic systems ultra-oligotrophic (Figure 3). Such a phenomenon is referred to as ‘cultural oligotrophication’ and is more prevalent in systems with low mean annual water temperatures regimes, short growing seasons, granitic geology, and nutrient poor watersheds. The change in nutrient status from oligotrophic to ultraoligotrophic may occur over a time span of decades. The authors explain that the ‘clear water paradox’ of aquatic ecosystem restoration occurs when “Western society wants crystal clear public waters and ecosystem services or benefits like harvestable fish populations but simultaneously enforces water quality standards that limit or prohibit the biological productivity and ecological processes required to produce and maintain those benefits" (Anders & Ashley, 2007 p. 126). Anders and Ashley concluded that

> rather than asking fishery and water resource managers to choose between clear water or valued ecosystem services, education and effective ecological restoration involving biologically productive middle ground, where appropriate should provide a scientifically defensible strategy for restoring culturally oligotrophic ecosystems. (Anders & Ashley, 2007, p. 127)

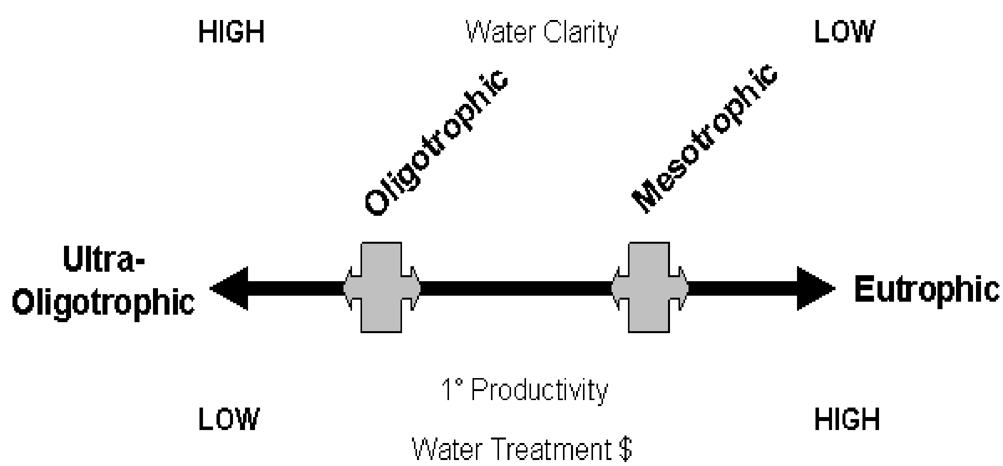

Figure 3: Implications of Cultural Oligotrophication (Adapted from Anders & Ashley, 2007).

Case Studies in British Columbia and the USA Pacific Northwest

BC Hydro – Coquitlam / Alouette

Consideration for the restoration of salmon in BC Hydro's Bridge Coastal Generating Area Facilities was documented staring in 2001. According to Bengeyfield

(2001), the re-introduction of anadromous species in Coquitlam was not viable due to inter-basin diversion effects as well as significant reservoir drawdown, domestic water supply considerations, and limited upstream habitat capability, which provide “major or likely major impediments” to restoring fish (Bengeyfield 2001, p. 37). The Alouette Reservoir was also not recommended for restoring historic fish passage due to the inter-basin diversion effects although domestic water supply and significant drawdowns were not identified as major impediments.

Bocking and Gaboury (2002) produced a report entitled “Framework for the evaluation of restoring historic fish passage for anadromous fish at BC Hydro Bridge-Coastal generation Area Dams”. This report questions the results of Bengeyfield (2001) based upon lack of evidence for the conclusions and suggests further analysis and experimentation is required. Bocking and Gaboury (2002) indicate that in order to assess fish passage feasibility, a four-stage expanded decision-making process is required which consists of:

1. Establishing stock and habitat profiles;
2. Establishing operational profiles;
3. Establishing structural profiles; and
4. Assessing cost effectiveness.

Additionally, they recommended an assessment of anadromous fish re-introduction on domestic water quality be undertaken. It suggests the importance of field tests to determine the implications of inter-basin water diversion on out migrants and spawning populations as well as impacts to resident fish populations.

Bocking and Gaboury (2003) indicated the re-introduction is feasible based upon a recommended carrying capacity of 50,000 spawners that would have a small and possibly negligible impact on drinking water quality. The authors further indicated the re-anadromy of Coquitlam Reservoir kokanee is possible and can contribute to the building of the stock while additional donor stock propagation will likely be required. In 2006, an Assessment of Coquitlam Rearing Capacity indicated that the reservoir could support 10,000 spawning adults based upon empirical data for zooplankton and kokanee production. This data indicated that the reservoir could support a relatively small sockeye smolt population estimated at 400,000 (Bussanich et al., 2006).

Starting in 2005, kokanee smolts were first released through the low-level outlets (LLO) with an escapement of 1,500 recorded below the dam. The releases were undertaken between late April and early June, with Bunzten Tunnel closed for two-week periods to draw smolts south towards the lower Coquitlam River. Smolt out-migrations from the Coquitlam Dam have steadily declined to less than 30 in 2008, although 269 were recorded in 2009. The first two adults returned to the base of Coquitlam Dam in 2007, with eleven returns in 2008 but only one returned to the base of the Coquitlam Dam in 2009 (Figure 4). There is little surprise regarding the adult returns given the low smolt out-migration in 2007 and the revised sockeye run projection for 2009.

The 2007 BCRP Report "Potential Risk of Change in Water Quality in the Coquitlam Reservoir from Re-introduction of Sockeye Salmon: Final Report of the Expert Panel" concluded that there is low risk of change in water quality for the Coquitlam water supply through the proposed re-introduction of sockeye salmon (Perrin et al., 2007). A number of sockeye population scenarios, some beyond the estimated carrying capacity of the habitat were utilized for this study but all concluded a low risk to change in water quality. It was also suggested that the risk to water quality could be classified as very low if the spawning occurred beyond or north of the Cedar Creek drainage which lies approximately 6 km from the MV water intake.

Figure 4: Spawning sockeye that returned to the base of the Coquitlam Dam in 2008 being released into the Coquitlam Reservoir. (Source: David Dunkley, 2008).

Successful smolt out-migration is a complex issue that is dependent upon many factors that interact within the system. Smolt populations, water temperature, reservoir level, and discharge as well as the operation of the Coquitlam Dam and Buntzen Tunnel will all affect the timing and mortality of the out-migrants. It will cost BC Hydro revenue in the form of lost power generation opportunity to manage the fishery when the Buntzen Tunnel is out of service during such periods to draw the smolts south towards the dam and the lower Coquitlam River. Natural out-migration periods vary greatly but generally occur between late April and early June.

The only way that smolts are able to out-migrate through the Coquitlam Dam is by utilizing the low-level outlets (LLOs) or small fish release valves that were constructed in the early 1900's. Sockeye and coho smolts however, prefer to out-migrate on the surface according to Sandercock (1991), and there is no free spill from the Coquitlam dam crest except during severe weather events. Unfortunately, the use of the five LLOs and two fish release pipes also produces a relatively high mortality of approximately 30% for the outgoing smolts. A fluctuating water level in the reservoir further complicates out-migration from an historic dam that was not specifically designed with fish passage in mind. When the reservoir elevation was dropped and the flow through the Buntzen Tunnel was reduced to facilitate smolt out-migration through the Coquitlam Dam, BC Hydro lost $600,000 in generation revenue between April 15 and May 15, 2008 (BC Hydro, 2008). During this period of time a total of only 33 smolts were trapped below the dam.

In 2009, a trial was conducted to evaluate out-migration potential by releasing tagged coho smolts into the forebay of the Coquitlam Reservoir (J. Bruce, personal communication, July 1, 2009). The difference between the number of reservoir smolts which were trapped downstream of the dam were compared to an identical number that were tagged and released in the tailrace below the structure itself. The study concluded that there was an obvious difference in the smolt migration pattern between the reservoir and immediately below dam release locations which suggests that the structure itself may present a significant barrier to out migration. "Whether this is something related to water depth, is due to confusion as a result of tunnel operations, or is inherent inability to cue discharges at depth remains uncertain" (J. Bruce, personal communication, July 1, 2009). It was also suggested that predation by Northern Pike Minnow and cutthroat trout in the forebay may also be contributing to the low out-migration numbers observed. A net trap that was placed into the forebay location during the 2009 out-migration period only produced one coho smolt and one kokanee (nerkid) smolt during the period of May to June. The remaining fish trapped were Northern Pike Minnow (8), cutthroat trout (4), rainbow trout (1), and peamouth chub (1) (J. Bruce, personal communication, July 1, 2009).

When assessing the feasibility of re-introducing salmon to the CWSA, Bocking and Gaboury (2003) suggested that fish passage can be managed over a ten-year period through a trap and truck operation at $1.25 million or a constructed fishway estimated at $7.5 million. Bocking and Gaboury (2003) further indicated that even if re-anadromy is successful additional stock propagation would likely be required at an estimated cost of $2 million which also includes the funding of ongoing studies over the same ten-year period. Stock propagation could be facilitated by the use of suitable donor stock.

Fish restoration in the Alouette watershed was undertaken under the terms of an original 1996 Water Use Plan, which was reviewed in 2006. Since 2005, springtime water releases have enabled the annual out-migration of kokanee smolts to reach the ocean. Outward-migrant numbers from the dam were estimated at 7,900 (2005), 5,064 (2006), 62,915 (2007), 8,257 (2008) and 4,000 (2009) respectively. Twenty-eight spawning adults returned in 2007, 54 in 2008, and 40 in 2009. While the timing of restoration of the Alouette coincided with the start of the restoration efforts at Coquitlam, it appears the former has shown consistently better results (See Table 1). This may be attributed to the fact that the Alouette Dam utilizes a surface spill release to facilitate smolt out-migration and the reservoir is fertilized which has the potential to increase the system's productivity and benefit salmon production in general.

Table 1:

Case Study Comparison of Coquitlam and Alouette Reservoir Fish Re-introduction

	Coquitlam		Alouette	
Year	Out-migrating Smolts	Returning Adults	Out-migrating Smolts	Returning Adults
2005	1,500		7,900	
2006	800		5,064	
2007	280	2	62,915	28
2008	40	11	8,257	54
2009	269	1	4,287	45
Total	2,889	14	88,423	127

(Source: BC Hydro (2008), and D, Hunter, personal communication, January 28, 2010)

MV – Capilano and Seymour Watersheds

Since 1959, spawning coho have been trucked around the Cleveland Dam on the Capilano River and released into the upper watershed to complete the spawning phase of their life cycle. While adult coho will spawn in the upper river, the migrating smolts are only recently trapped in the lake and transported below Cleveland Dam which presents an otherwise formidable obstacle to successful smolt out-migration. There is no indication of associated water quality impacts that can be attributed to the fish restoration efforts that have occurred within the Capilano Watershed since 1959. This is despite the release of 5,000 adult coho annually into the river above Capilano Reservoir. A lack of detailed monitoring data for many years however, cannot rule out that a change in water quality has or has not occurred.

In the Seymour Watershed, spawning adults are not transported into the upper basin due to the small size of the reservoir in relation to the concerns which have been raised for the potential to impact water quality from this source. Coho fry release does occur however, above the dam in the upper Seymour Watershed on an annual basis. Through the fish considerate configuration of the Seymour Falls dam, smolt survival remains relatively high despite the 30-meter drop into a plunge pool below.

Seattle Public Utilities

The Seattle Public Utilities (SPU) completed a multi-species Habitat Conservation Plan (HCP) for the Cedar River Watershed in 1994 to comply with the federal Endangered Species Act (Montgomery Watson Americas, 2001). Under the HCP, the SPU committed to providing fish passage past the Landsburg dam on the Cedar River to access 17 miles of anadromous fish habitat blocked by the dam. Fish passage was restored over the 26-foot high dam after 2002 through the construction of a fishway at a cost of US $7.5 million (G. Sprague, personal communication, January 26, 2010).

In 2003, the Seattle Public Utilities began re-introducing anadromous species into their water supply area as identified under the terms of the HCP. The SPU primary water quality concern involves phosphorus loading and eutrophication impacts to Lake Youngs, which provides water to one million downstream customers (Herrara Environmental Consultants, 2008). To date, monitoring data and modelling suggests there is little to no risk of degrading water quality of Lake Youngs provided the number of salmon above the dam does not exceed 1,000 chinook and 4,500 coho, or the equivalent of approximately 46,500 pounds of salmon (Herrera Environmental Consultants, 2008). It is interesting to note that the addition of fluoride (fluorosilic acid) to the water at the Landsburg Treatment Facility increases phosphorous loading by 21% compared to an estimated 0.5% through the contribution from salmon carcasses.

The SPU has developed an adaptive management plan to evaluate and mitigate water quality impacts resulting from salmon re-introduction. Possible mitigation measures may include:

- Reduction of phosphorous to Lake Youngs by reducing fluoridation;
- Reduction of phosphorous loading to Lake Youngs by reducing the amount and changing the timing of water diverted to the lake;
- Improving water quality of the raw water supply through selective withdrawal and whole lake mixing; and
- Restricting the number of adult coho salmon above the dam by fish ladder manipulation or manual removal of the carcasses (Herrera Environmental Consultants, 2008).

The restoration of salmon by the SPU above Landsburg Dam clearly indicates that fish passage constraints of the original dam have been successfully overcome with the construction of a fishway, which allows returning adults to access the upper Cedar River system in addition to the downstream escapement of smolts. Additionally, water quality impacts since the re-introduction began have been negligible to date and the development of an adaptive management plan to address water quality / fish interactions should satisfy water managers that impacts if detected can be successfully mitigated.

Baker Lake

Puget Sound Energy (PSE) operates a 190-megawatt hydroelectric facility at Baker River in northwest Washington State. Baker River is a tributary to the Skagit River and is “one of Washington State’s most prolific waterways for fish” (PSE, 2009, p. 1). Two large dams on Baker River have provided large-scale power production and supply to 60,000 households but have reduced access to habitat for a number of anadromous fish species. Since the construction of the dams in 1925 and 1959, the utility has been actively pursuing fish restoration strategies and has made significant progress towards enhancing coho and sockeye populations in recent years. Both dams successfully utilize a trap and truck program to move out-migrating smolts into the lower river system and adults to the reservoir-spawning habitat.

A settlement agreement for a new 50-year operating license for the Baker River Hydroelectric Project provides business certainty to the utility and benefits that will further enhance the salmon resource. In 2004, after five years of work, PSE and 23 stakeholders unanimously agreed on the proposed conditions of a long-term lease, the highlights of which include further enhancing fish populations in the Skagit-Baker watershed through new upstream and downstream fish-passage facilities and riparian habitat protection in addition to a new fish hatchery. Specifically, the plan calls for a new US $50 million floating surface collector to gather the smolts and the expenditure of US $360 million in license-related proposals which hope to quadruple the returns of adult salmon to the system (PSE, 2008).

The Baker Lake sockeye annual returns have averaged approximately 3,000 spawners since 1926 with an all time low of 99 fish recorded in 1985. The combined efforts of PSE, government agencies, Indian tribes, and environmental organizations since the mid 1980’s have resulted in six of the largest runs occurring in the last decade. A record 20,225 adult sockeye returned to spawn in 2003 (PSE, 2008). While the ongoing costs to restore salmon to this system are substantial, they appear justified in the eyes of the utility. Such costs will inevitably fall onto the backs of the consumer who will indirectly support the restoration of a sustainable population of anadromous fish to Baker Lake now and into the future. The Baker Lake initiative has demonstrated that a sustainable sockeye population can thrive when restoration efforts are able to overcome issues of barriers to fish passage.

Summary

This concludes the literature review of my research question concerning the re-introduction of salmon to the CWSA. In the following chapter, I lay out the methodology that was utilized to conduct the research, gather the data, and derive the conclusions and recommendations.

CHAPTER THREE: METHODOLOGY AND DATA GATHERING

The research methodologies, including observations, interviews, and documentation that were utilized to gather the research data and interpret the results are presented. The research material was organized into distinct categories or themes that relate to fish passage, water quality, fish biology, and sustainability.

Case Study Methodology

The evaluation of potential water quality impacts and fish passage constraints concerning the re-introducing salmon to the Coquitlam Water Supply Area followed a case study approach as defined by Yin (1994). Case studies involved an approach which "investigates a contemporary phenomenon within its real-life context; when the boundaries between the phenomenon and the context are not clearly evident; and in which multiple sources of evidence are used" (Yin, 1989, p. 23).

This methodology involved four stages (Yin, 1994):

1. Designing the case study;
2. Conducting the case study;
3. Analyzing the case study evidence, and;
4. Developing the conclusions, recommendations and implications.

Yin (1993) described three types of case study: exploratory, explanatory, and descriptive. An exploratory case study methodology allows for the collection of data and fieldwork prior to defining the research question and ahead of some social research (Corcoran, Walker, & Arjen, 2004). As this approach was determined to have met the research requirements with the re-introduction of salmon to the CWSA, I have undertaken it for my case study research methodology. Applicable case studies from other regional systems were summarized as they pertain to the research question. The data collected was based upon individual observation, interviews, and documentation sources.

Observation

Research information was gathered based upon observation and subsequent data gathering at project advisory and municipal government meetings involving fish restoration within the reservoir area. These meetings provided a good overview of the current issues and ongoing developments from a wide variety of perspectives.

The Kwikwetlem Salmon Restoration Program (KRSP) Advisory Committee meets bi-annually to discuss progress and report on issues concerning the sockeye re-introduction. Members of this committee include representatives from the Department of Fisheries and Oceans, Kwikwetlem First Nations, Metro Vancouver, BC Hydro, Watershed Watch, the City of Coquitlam, the City of Port Coquitlam, as well as various members the environmental community. I attended one of these meetings in the capacity of an observer. This meeting provided an opportunity to observe the various stakeholder perspectives and also provided an overview of the funding challenges that exist to facilitate the re-introduction efforts.

The Metro Vancouver Water Committee and Environment Committee meet on a monthly basis and I attended one of these meetings when issues concerning the restoration of salmon in the Watersheds were present on the agenda. Such meetings allowed the researcher to ascertain the regional government's perspective concerning the restoration of the salmon resource in the Capilano, Seymour and Coquitlam Watersheds as well as the specific concerns regarding the potential to impact water quality from these sources.

Interviews

A formal Ethical Review to Conduct Research was completed and submitted for approval by Royal Roads prior to undertaking research. In-depth interviews are a qualitative research technique that allows for individual consultation to explore the perspectives on a particular idea, program, or situation (Boyce & Neale, 2006). The advantage of such interviews is that they provide much more detailed information than what is available through other data collection methods, such as surveys (Boyce & Neale, 2006).

A list of potential interview subjects was developed based upon candidates who have had involvement with this project and/ or expertise in water quality or fisheries management. While a total of ten Invitations to Participate were sent out between September and December 2009, six participants responded positively and agreed to formal interviews. In all cases, the anonymity of the interview subject was explained as was the participants right to withdraw from the research project if desired at any time. All interview subjects agreed to sign a letter of consent to participate as interview subjects.

A list of four questions with a number of associated sub-questions was developed and subsequently refined to more adequately reflect the intent of the research. These questions were designed to allow the interview subjects to not only consider the potential risks to water quality and fish passage constraints but also the broader issues of sustainability. The four questions posed to the interview subjects were:

1. Why is the restoration of sockeye salmon important to you and your organization?
2. What are the main challenges or limiting factors in sustaining the Coquitlam sockeye? Can these challenges be mitigated or overcome?
3. What are the benefits and impacts in restoring this population from a social, environmental, and economic perspective?
4. How do you measure the success of the program? What are the tradeoffs if any and are they justified?

Semi-structured interviews were conducted with the various parties at a number of locations within the Lower Mainland and were digitally recorded with the consent of the interview subject. The use of semi-structured interviews allowed the participant to determine the scope of the subsequent discussion based upon the four questions which were posed. Sometimes clarification and further information was requested from the interview subjects where uncertainty or ambiguity was encountered. A font color code was assigned to each interview subject and this proved very helpful in amalgamating the data into common themes for presentation in the results and discussion section while ensuring complete anonymity. Members of the environmental community, fisheries biologists, water quality experts, and the Seattle Public Utilities were also contacted for information concerning my research project but were not formally interviewed.

All interviews were transcribed by a professional stenographer and filed according to the research criteria previously mentioned. The data collected during the interviews has been treated with the strictest of confidence and will be destroyed after six months.

Documentation

Numerous document sources concerning the potential restoration of salmon in the Coquitlam Water Supply Area were used:

1) Peer reviewed literature on salmon restoration.

2) BC Hydro and other case studies.

3) MV project documentation concerning salmon restoration in all three watersheds.

4) MV archives.

Data Analysis

Data was collected from a variety of sources, and compiled according to the research criteria. I utilized Berg's (2004) stages of data analysis in analyzing my research data. Berg (2004) presented a stage model to analyze data where data was read, sorted, and placed into categories, and the resulting patterns then considered in relation to the number of entries in each category. Additionally, he suggests an explanation of the findings should be presented as a means of identifying patterns with regards to the literature reviewed. The analytical process began early as the gathered data was from multiple sources. This adaptation of the Berg model has allowed me to revisit and refine my area of inquiry.

Once the interview transcriptions were complete, I undertook to review the information gained. The data was organized into applicable themes including water quality, fish passage, fish biology, and sustainability. As key themes emerged, I identified quotes and information that would support the analysis of my research question. Through this process a comprehensive data set was created which facilitated the presentation of my results.

CHAPTER FOUR: RESULTS

Introduction

This chapter presents the findings in relation to my research question; "To what extent do existing fish passage constraints and potential water quality impacts to the domestic water supply limit the sustainability of re-introducing sockeye salmon to the Coquitlam Water Supply Area?" Findings are presented based upon the interviews in addition to the literature and case studies presented in Chapter Two.

Study Findings

I interviewed six individuals who are involved with fisheries management and water quality issues or both. These individuals shared their valuable experience from a personal and an organizational perspective. The resulting information allowed me to present findings by utilizing anonymous quotes from the interview transcripts, numbered 1-6, in order to represent the six interview subjects. As such, these identifiers are used following each quote.

The initial interview question was to describe why the restoration of sockeye salmon was important to the individual and the organization. Responses to the question were varied but identified several common themes amongst the majority of participants in regards to correcting past mistakes and living up to broader sustainability goals that the respective organizations now adhere to. As stated by one respondent:

> ….in a historical sense, no one did this intentionally but I think it's incumbent upon us, particularly as the world changes and the stresses become more pronounced – whether it's environmental, or cultural or whatever it be, that it's incumbent upon us to address this and rectify it and make it right. (4)

Another interview subject concurred and provided the following: “But back when our facilities were built there wasn’t really the legislation there to do anything. So us being held accountable I think is reasonable, and yet there was [a] viable run of sockeye and we’ve blocked their way” (2). The following comment sums up the efforts of both organizations with respect to salmon restoration “…trying to put back, trying to make it right to the best of your ability” (3).

The second question posed to the interview subjects was to identify the main challenges or limiting factors in sustaining the Coquitlam sockeye. A sub-question asked if these challenges could be overcome or mitigated. Again, a number of diverse responses were provided through which common themes were identified concerning fish passage, water quality (for humans and fish), and fish propagation. One response suggested the main challenges involve “Getting them in and out…having a sustainable population…looking at the drinking water aspects…” (4). Regarding the convergence of specific themes, the majority of the interview subjects suggested that the existing fish passage is a chief issue of concern where one respondent was quoted as saying: “The main challenge is access in and out at the correct time of year for the correct life history stage. Adults coming back, and then smolts going out, so I’d say passage is the key thing” (5). Regarding the current situation at the Coquitlam Dam another respondent noted “there’s a lot of just straight physical challenges because the Coquitlam Lake is now a reservoir and there’s a 30-meter high dam. So there are some physical challenges around adult migration and smolt migration” (1). Another respondent added:

> But also the fact that we don’t have a surface release at Coquitlam, typically the sockeye smolts surface, really migrate at the surface so our low outlet into the

> river is at depth. So what implications does that have on surface migrating fish? It is potentially significant… (2)

The sub-question regarding mitigation and overcoming fish passage challenges was answered by several respondents who suggested fish passage could be overcome by utilizing an effective trap and truck operation. One respondent offered: “I guess getting them up into the dam, over the dam, which I would see the “trap and truck” being the most reasonable method of doing that” (2). This option is supported by the case study literature on Baker Lake.

Water quality was identified as a concern for both fish and domestic water supply but for very different reasons. According to the literature, the ultra-oligotrophic status of the Coquitlam Reservoir is a limiting factor in the production of fish while any change to the same nutrient status through the re-introduction of salmon may have impacts on drinking water quality. Several respondents indicated that while the potential to impact water quality was low, MV still had a responsibility to investigate the potential ramifications to its water supply and treatment cost. One respondent stated:

> …will drinking water be impaired? As an organization that’s our prerogative, it’s our due diligence. We have to examine this. Based on the evidence I’ve seen so far for small numbers, meaning probably less than 5,000 or 10,000, and it’s all preliminary, but I think we’ll be okay on the drinking water side here from those type of numbers. But I’m just speculating at this time. I’ll have to wait for the experts. (4)

Another individual echoed these thoughts:

> We've taken quite an interest in this because Coquitlam is our unfiltered source in the future and any changes to the water quality or even to the ecology of the reservoir we would be concerned that this might lead us to more treatment in the future. So we're supportive of this process, it has lots of merits. But on the other hand, we are taking a precautionary approach with our water supply to ensure that we won't end up with water quality issues that will require additional treatment in the future. (1)

From the perspective of a change in water quality from the contaminant burden through the introduction of salmon and the risk it imposes, one interview subject stated:

> But in that context, the sort of contaminants…I looked at the potential of fish to bring contaminants back into the lake that they pick up from the ocean. I look to things they pick up out there. I picked mercury because it's volatile and moves around the atmosphere, I picked PCB's because we know they move around the atmosphere. And there are some studies that have been done, for example, in Alaska where they've taken lake cores, where they have sockeye salmon and where they don't have sockeye salmon, and you can see the PCB label in the sediments from those returning sockeye. So that's one important thing. Given the kind of numbers that would come back, I looked at some concentration data of mercury and PCB's on returning Pacific sockeye and then the kind of dilution that would occur, and I mean it was orders of magnitude lower than what we'd ever been able to measure. (6)

Concerning the potential for detrimental impacts to water quality through possible increases in *Giardia* and *Cryptosporidium* micro-organisms the same respondent stated

"…again [with] the dilution that would occur, I don't think there's much risk with those pathogens" (6).

It was suggested that it is in the best interest of MV to maintain the status quo because the utility "essentially wants no net impact of any potential sockeye introduction on what's expected to be the predicted cost of treating the water to the Canadian Drinking Water Standards Board" (5). He further elaborated on the 'clear water paradox' in his response which indicated:

> The main obstacles in this is the prevailing engineering and public health paradigm that water has to be protected at all costs and that anything being introduced into water is bad. A 'Clear Water Paradox' is where it says there's legislation to restore salmon and then there's legislation to keep water as clean as possible and so they're at odds with each other, even within a government…this apparent paradox that society wants salmon restored, and yet on the other hand they want clear drinking water. (5)

While many respondents indicated that the ultra-oligotrophic status in the Coquitlam Reservoir is limiting the productivity of the aquatic system, there was unanimous agreement that fertilization of the water body would be an unacceptable option to MV as the drinking water purveyor. One interview subject summarized the issue of fertilizing the lake as follows:

> Well of course, you put nutrients in the water and you grow algae and you stimulate the food chain. Well the potential for more algae leads to potential for taste and odour problems and those algae decompose; potential for forming more disinfection by-products from any kind of degradation products from the algae

> and things like that. And of course just the visual aspect, unless you filter the water, the visual aspects of turbidity of water due to phytoplankton, so that whole thing. So I don't think they'd ever do fertilization in Coquitlam Lake. (6)

Another respondent concurred, suggesting that:

> There is a nutrient loss with that dam in place. So you can make the argument if it weren't for the fact that it's used for drinking water supply, to make an argument for fertilization. But because you've got a drinking water supply that creates a major issue. That's a big barrier right there because you know [MV] will not start pumping in phosphorus pellets into the water and creating algae blooms and what not. It's just not going to happen. That's the biggest barrier. (3)

When the idea of fertilization was tabled at a KSRP meeting, one respondent suggested "as a drinking water person, specialist, we cannot have that and there's nobody in the organization that will accept that" (4). Relative to this, an interview subject commented on overcoming any water quality challenges to the domestic supply, if any, by mitigation through additional water treatment options. The following suggestions were made:

> If we had filtration, basically it almost becomes a non-issue because if properly designed, filter plants - particularly if it's got ozone, at some stage in it you can oxide pretty much anything. So it's an unfiltered system that's under the surface water regulations you'll obviously have to be a little bit more concerned about what goes on in there. (5)

According to another respondent:

> That combination of UV and ozone is pretty good too, but again you need some long-term disinfection. The other thing of course would be to go to some sort of

> filtration, especially first core central filtration and then if you want to remove organics, carbon column. The technology is there. (6)

In addition, a number of individuals suggested that the existing kokanee population may be a limiting factor as it is unknown whether the current run can be adequately restored to the status of a viable self-sustaining population. This opinion is repeatedly reflected in the literature and a number of strategies have been suggested to overcome this barrier. As such subsequent approaches have proposed to utilize donor stock or a hatchery to propagate the run. One participant suggested:

> To have a viable run to have to get to a viable number and of course we're a long ways from that. No adults returned in 2009. We did have 10 returns last year which is promising but we're a long ways from what one would consider a viable sockeye run. (1)

With the low population numbers and a run that is currently not self-sustaining some respondents indicated the options available to propagate the population of sockeye salmon. One indicated:

> The hatchery donor stock was originally on the table a long time ago. They did some feasibility on different hatchery locations around the province, lower mainland specifically, how much they would cost. That was almost sort of put on a lower level, we wanted to look at the re-anadromy option but if that doesn't seem possible, maybe the hatchery donor stock will be looked at more seriously and I tend to think that's where it's going. (2)

Several individuals also felt strongly that the residual kokanee should be the focus of future propagation efforts in order to maintain the genetic traits of this population which are well adapted to the conditions within the reservoir. One respondent stated:

> I would rather just do re-anadromy and the reason being is that you've got a stock of kokanee who are well adapted to reservoir conditions. They've been subjected to it for eons. A lot of the genes…a lot of the gene pool would have not given you that protection. (3)

Another respondent shared similar thoughts:

> But still, it's protecting that one little diverse stock it's almost like…the stock has its importance regardless of the impact on the sport or the commercial [fishery]. I think it's the whole endangered species and stuff like that and protecting them, those stocks. (2)

The third question posed concerned the benefits and impacts in restoring the population from a social, environmental and economic perspective. From the issue of sustainability, a number of distinct themes emerged from the interview data which relates to the social, environmental and economic realms of the re-introduction efforts. From a social perspective many agreed that this is an important issue to society at large. One interview participant suggested:

> I mean I think sockeye salmon are important to all British Columbians. It's a symbol they hold up there as our heritage. It's part of our heritage and there used to be sockeye salmon [in] Coquitlam Lake and having sockeye salmon back there is restoring part of our heritage that's been lost. (6)

As well, the majority of the respondents identified the benefits that the First Nations would incur based upon a successful sockeye restoration. For instance, an interviewee noted, “So that’s the big social hit, is that salmon is so much part of the culture and social makeup of West Coast natives” (5). Another respondent added:

> … I think another benefit is going to be, we never mentioned this, but First Nations people have been pushing this quite a bit. Their heritage is tied into it even more than ours because they have various rituals as well as an important food supply. It’s much more important to them, that symbol of the salmon. I mean look at their totem poles on the coast. How the salmon was important as well as the raven and the bear. It was key. (6)

Supporting the above statements regarding First Nations in general, several participants specifically mentioned the Kwikwetlem:

> And then if we want to get down to the Kwikwetlem First Nation, their whole lives are tied to the fish…I think this is an opportunity for them to re-establish, restore their cultural identity and I think we’re better off for that because we can learn things from them. (2)

Considering the environmental benefits of the restoration it was interesting to note that none of the interview subjects voiced any environmental impact concerns. One subject said:

> Spawning salmon would come in and they would die and they would provide some nutrients to the invertebrates, salamanders, you know. There was a report that came out of Washington Department of Fish [and] Game that came out a few

> years ago that said there was 137 different species of vertebrates that depended on spawning salmon at some time in their life history. (5)

Ecosystem goods and services were also mentioned when a participant stated:

> And the value of that is often not taken very seriously until you start prying into the nuances of this ecosystem goods and services that you can think of something, because it's safe for salmon to come in there and spawn that you then get nutrients being moved up into the riparian area, that increases the growth of the recurring vegetation that grows faster and healthier trees there ties in the riparian tree corridor on the river, either side of it, makes it more resistant to erosion and it actually keeps the water clear. (5)

From an economic perspective most respondents focused on the cost required to restore salmon as well as the fact that perhaps the funds could be spent on alternative restoration initiatives with better results. It was suggested that "it might be expensive. It might be even more expensive than I think it's going to be. So I guess that tradeoff would be that money could be best put elsewhere, more than anything, for environmental benefits" (4). Another interview subject added:

> BC Hydro will be spending probably a lot more money on other initiatives relative to re-establishing the run, so it does add up. Somebody just has to ask the question is this the best spot to spend these funds if these are scarce funds and you are trying to restore habitat. Sometimes you can put money in other places to get a bigger bang for your buck. (1)

Similarly, the following statement:

> It's recognition of the past impacts but it's also you're fighting for dollars. You're competing for dollars for upgrades to facilities. Do you want long-term sustainability…do you buy a new bearing for a turbine or do you fund the fish? So it's a lot of competition for resources type of thing. (3)

Several respondents also mentioned the true cost of water which considers ecosystem benefits in addition to the provision of a domestic water supply and power production. This is reflected in the following statement:

> And so what you get is the true cost of having what you got. Because it just has to encompass fish passage. It just becomes the cost of doing business. Just like a filter plant, just like the fenced stock intakes, just like an ozonater. It's the whole thing and that's multi-species use of a watershed resource, rather than here where water was seen to come from a tank in mountains and you wanted it. It was purely for human purposes. So that's the new paradigm that those in the know are thinking about. (5)

The final interview question asked how one would measure the success of the program and whether or not there are tradeoffs that could be justified. While many respondents indicated that a number of returning adults was a good measure to indicate the success of the program, no common or minimum number was identified amongst the six subjects and the responses ranged from between zero and 5,000 spawners. One participant suggests:

> Success…well, I guess you have to look at the returns that you get, given the number of fish that migrate downstream. That's the way we look at success.

> Also, I would think you would also want to look at their growth, size characteristics, and their health relative to some sort of reference population. (6)

One interview subject also questions the long- term feasibility of the project when he states:

> At the end of the plan you would have assessed all the options and I guess if you got to the end of that plan and none of them are feasible then you would say it's not feasible. But I guess I always see that based on injecting enough money into something you can perhaps say it's always going to be feasible. (2)

Lastly, an individual summarized their desired outcome of the restoration efforts:

> In a perfect world, it would turn out to be sort of a self-sustaining run of say 5,000-10,000. That would be the best thing. That everybody wins because you get some energy out of the system, you get some clean water out of the system that doesn't have a high cost for treatment, and the First Nations get back what they used to have in terms of their social and ceremonial use, and that the ecosystem function of having salmon come back so the ravens and the bears and everybody else get something to eat before winter hits. That would be the win, win, win situation. (5)

Summary

This concludes the facts, ideas, and opinions that became my study results derived through interviews. This methodology elicited rich stories and insights from the participants regarding fish passage, water quality, fish biology, and overall issues of sustainability as it pertains to salmon re-introduction in the CWSA. These broad topic areas are discussed in the next chapter to gain greater insight into my research question.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

There is no doubt after extensive review of the literature and interview data that the existing fish passage at the Coquitlam Dam is problematic. In particular, the sockeye smolts have a difficult time finding their way out through a structure that was simply not designed with consideration of fish passage. While the lack of a surface spill during the out-migration period is a concern, there appears to be solutions available to mitigate the anthropocentric barriers to fish passage. Such options include an effective trap and truck operation in addition to the more costly but permanent installation of an engineered fish ladder. The SPU and Baker Lake case studies provide viable fish passage alternatives but may be costly to construct and maintain.

Cultural oligotrophication and the ‘clear water paradox’ reflect the dilemma that MV has unknowingly encountered as it struggles between fish restoration and the provision of clear drinking water to the region. From the literature and the interviews, there is a low risk to water quality and the ecosystem will undoubtedly benefit from the re-introduction efforts. It would be diligent to determine at what number of spawning salmon are the impacts to water quality detectable and at what number do they become a public health issue from a water treatment perspective. Anders and Ashley (2008), refer to a biologically productive middle ground approach that would facilitate the restoration of the aquatic system while maintaining the provision of high quality drinking water. The relatively small carrying capacity of the reservoir is also likely well below any potential to detrimentally impact drinking water quality. In all likelihood the issue could be controlled and managed by only allowing a certain number of salmon above the dam to complete their natural life cycle.

While it is evident that the existing fish passage constraints have impacted the ability of smolts to out-migrate into the lower Coquitlam River, the population is not self-sustaining at this point based upon re-anadromy alone and is in need of anthropocentric assistance. Can a viable population overcome the existing fish passage challenges by shear numbers alone or is success co-dependent upon one another? The successful propagation of the run by donor stock or the construction of a hatchery should take precedence as the restoration efforts continues. Many respondents supported the use of the existing kokanee to build the stock. This strategy would be consistent with the federal Wild Salmon Policy which is intended to maintain genetically diverse stocks of salmon.

While the re-introduction of salmon to the CWSA has its benefits, several negative impacts are worthy of discussion. Most impacts are related to the financial burden that will be required to restore and maintain the Coquitlam Reservoir sockeye now and into the future. The utilities have many key decisions regarding large capital projects which will be undertaken in the coming years and which will also have huge financial commitments. While the salmon restoration is a good news story, it does need to compete for limited funding amongst other essential capital works. Ultimately the decision to restore salmon will be politically driven to reflect public opinion on the matter.

Conclusion

The review of the data enabled me to conclude that the existing fish passage is a significant limiting factor in sustaining the Coquitlam Reservoir sockeye population. The various case studies and literature however, have suggested that fish passage obstacles may be overcome by utilizing an effective trap and truck program or ultimately through the construction of an engineered fish ladder.

Literature findings as well as interview results allowed me to conclude that the risk to change in water quality as a result of the re-introduction is low. This, of course, is ultimately dependent upon the number of returns above the dam although at the expected carrying capacity of the system, water quality will not be impacted and as such is not considered to be a limiting factor to sustainably re-introducing sockeye to the CWSA.

Critical to the success of the re-introduction is the establishment of a sustainable run of sockeye salmon. I therefore conclude that the existing reliance of the Coquitlam sockeye to build a self-sustaining population based solely upon the re-anadromy of the reservoir kokanee is a limiting factor to the success of the re-introduction efforts. It is evident that the use of donor stock or a hatchery will be required to build a self-sustaining population.

The restoration of the Coquitlam sockeye to a self- sustaining population would greatly benefit the local ecosystem, First Nations, and the communities of the Lower Mainland. The re-introduction of sockeye salmon to the Coquitlam Water Supply Area will also showcase the MV and BC Hydro commitment to sustainably managing a previously extirpated species for conservation while supplying clean safe drinking water and power to the downstream communities. While there are many challenges to ultimately attaining this goal, the effort involved has great potential to be socially supported, economically viable and environmentally beneficial.

CHAPTER SIX: RECOMMENDATIONS

A total of three recommendations have been formulated based upon the research which has been conducted, and are as follows;

1. Continue monitoring water quality to discern impacts if any and consider the development of an adaptive management plan to deal with fish and water quality interactions that may occur in the future.

2. Utilize a trap and truck program at the present time while the sockeye population is propagated to a self-sustaining number. Once the population is well established more permanent and costly fish passage options may be considered.

3. Metro Vancouver should undertake a detailed cost-benefit analysis on the re-introduction efforts that are underway in Coquitlam. The MV utility benefits from the provision of an impounded reservoir for domestic water supply purposes and should therefore share the costs of the restoration efforts. Such an approach would more closely reflect the true cost of supplying drinking water to the region from an environmental impact perspective.

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APPENDIX A

Figure 1:

Location map of the CWSA