"I do ride my bike along part of Still Creek when I go out to the Burnaby Art Gallery. There is a great overpass from Sperling Skytrain that overlooks the creek and it was from there that I have seen some of the returning salmon. I always watch for them. Pretty exciting. I have always thought it would be neat to do a canoe trip down the creek. Some misty morning. Wild in the city."

- Pat Beaton, Burnaby Art Gallery

"...the Renfrew Ravine has always been sort of loved and feared, like loved by the kids and feared by the parents...There was a dynamic community committee that was prompted in '96 because the neighbours were fighting over different things and they realized that the one thing we all agreed about is that the Ravine was a mess, let's clean it up."
- Carmen Rosen, Still Moon Arts Society

Abstract

The improvement or restoration of rivers, particularly those in urban environments, is a hotly contested issue. Challenges of trying to control or manage a natural, dynamic system, coupled with constraints and changes made by urban environments and decision-making that prioritizes humans complicate questions of improving rivers. Still Creek, a creek within the larger Brunette River watershed, which runs through Vancouver, Burnaby, and New Westminster, has recently been successfully restored to a degree that salmon have returned to spawn in 2012 for the first time in 80 years. The purpose of this paper is to discover how and why the governmental bodies, non-governmental organizations, and other stakeholders made the decisions they did to restore the creek, and then to analyze the decision making using literature and theory from the wider discipline of river management and improvement.

Introduction

Still Creek made the news recently as a success story of how urbanized streams can be restored, exemplified through the return of chum salmon spawning for the first time in 80 years in 2011. The Creek is part of the larger Brunette River watershed, which spans New Westminster, Burnaby, and Vancouver, and flows into the Fraser River. The area around the Creek is heavily urbanized and much of the creek is covered in culverts, making the return of the salmon that much more remarkable. River restoration is a large part of the work of fluvial geomorphologists due to recent motivations of governments and individuals to repair damage done by industrialization in the face of increasing concerns of "livability" and access to nature in urban environments. While the improvement of Still Creek has lead to tangible results like the salmon returning, the success is tenuous as only around 15 salmon returned in the fall of 2016. Fluvial geomorphologists Palmer and Bernhardt note that we need to acknowledge that even in enacting positive change, natural systems are comparatively dynamic and constrained (2006). Therefore the act of improving streams, particularly in constrained environments such as one so urbanized as Still Creek, must be further studied. The purpose of this report analyzes the choices made in the restoration of Still Creek through studying government documents, NGO reports, monthly data samples, and established river improvement theory. This analysis leads to suggestions for

continuing the restoration of Still Creek and what can be learned for other river improvement work.

River Restoration Theory

Though people have been undertaking river restoration activities for over a hundred years, there is little consensus on best practices or the one best method, partially due to the fact that rivers themselves are diverse with different forms and functions and different needs even within the same river. River restoration describes different modifications to water, sediment, and solutes as well as physical changes done to river channels, riparian zones, and floodplains (Bennett et al., 2011) with the goal of improving hydrologic, geomorphic, and/or ecological processes (Wohl et al., 2015). Generally, rivers can be damaged through urbanization processes that lead to changes in sediment load and water flow, lower water tables, loss of riparian zones, more intense flooding, and changes to biogeochemical processes that can lead to the extinction of species (Palmer & Bernhardt, 2006). Many river scientists believe that "restoration" may not be the best word to describe river improvement due to the challenge of restoring a river to a perceived prior situation, yet rivers are dynamic and constantly changing, without one true condition that the river once was (Wohl et al., 2015). The first type of river restoration was more human-centric and done for the purpose of enhancing navigation and ensuring the safety of property and people, leading to less diverse and more uniform river shapes (ibid). In the 1980's there was a general trend of environmental awareness, following the U.S.A.'s 1972 Clean Water Act, so river restoration began to emphasize fish habitat restoration, the reduction of pollutants through improving the riparian zone, and floodplain enhancement (ibid).

Currently there are three main theories or views of river restoration: 1) river restoration by hydrologists and hydraulic engineers based on the desire for flood control or irrigation; 2) restoration using hydrogeomorphic engineering that views rivers as natural, dynamic systems; 3) the incorporation of ecology into river restoration with a focus on species-based work and increasing biodiversity (Palmer & Bernhardt, 2015). As shown with the historical trends, clearly the third theory using ecology would have the most lasting positive impacts. Ecological literature views restoration as a process, with identifying goals that are based on ecosystem responses, so restoration should be conceptualized as such with the ultimate goals of improving the river's form, diversity, and river corridor dynamics (Wohl et al., 2015). More research is needed on best practices and solutions to improve these desired goals, albeit with the understanding that each river is unique. Even when the river may appear to be improved, there are three common themes that must also be emphasized in future research. Firstly, after actions have been taken there is still limited monitoring of the river and whether it is achieving the desired goals, and secondly, unfortunately many projects do not actually lead to water quality or biological improvements (ibid). Thirdly, multiple disciplines and non-scientific communities should be involved in the planning and implementation of such projects, particularly from local stakeholders who live near the river (Palmer & Bernhardt, 2006; Wolh et al., 2015). Palmer and Bernhardt (2006) recommend that the restoration work will be more effective if the fields of cultural anthropology, environmental education, landscape architecture, and city planning can come together, with hydrologists and ecologists joining to form the scientific basis. Furthermore, if scientists and planners are able to understand the values and needs of all stakeholders, the designs will be much more relevant and effective (Palmer & Bernhardt, 2006).

Background on Still Creek

Using this theory, the recently restored Still Creek can be analyzed to understand the effectiveness of the restoration work and to understand what future work needs to be done. Analyzing Still Creek also contributes to the literature by studying what changes were made based on what data, and gives real-life examples that future restoration work can learn from. The Creek is an artificially constrained waterway with gravel bedded reaches and lined or culverted reaches within the larger Brunette River watershed, which flows into the Fraser River. Still Creek is estimated to be the largest source of water for Burnaby Lake (Still Moon Arts Society, 2010a). The stream is a storm drain for about 2,400 acres of East Vancouver (ibid.) ranging from the headwaters beginning at 50th Avenue in Vancouver and Royal Oak Avenue in Burnaby to 29th Avenue at Renfrew Ravine between Boundary Road and Nanaimo Road. Much of it is located in culverts from Central Park until 29th, and again at Renfrew Park Community Centre until it reaches Burnaby. The areas Still Creek runs through were developed when the water management paradigm was focused solely on efficient drainage. Stormwater and other smaller streams were diverted into Still Creek. In addition to this larger increase in discharge, Still Creek underwent covering, straightening and lining, and development around it continued. It was assumed at the time that these engineering measures made development of the floodplain viable and the covering of multiple streams occurred all over the city, as seen from Figure 1 which depicts the "lost" streams of Vancouver. The reality ended up being that those modifications of Still Creek lead to significant and regular flooding.

Historically the area of Renfrew Ravine was logged, resulting in a predominately cottonwood and alder forest with invasive Himalayan Blackberries. At Renfrew Ravine, some sections of the bank have been altered with stone retaining walls and there are trails throughout Renfrew Ravine, some of which are close to the riparian zone (City of Vancouver, 2002). Though the watershed is highly urbanized, it provides a unique opportunity for humans to connect with nature (ibid.). Many animals make Renfrew Ravine their home, including squirrels, raccoons, opossums, mice, rats, skunks, coyotes, and many bird species. Salmon are locally known to have returned to spawn for the first time in 80 years in 2012, however in the 1950's some fish were still observed in Renfrew Ravine such as cutthroat trout, with the salmon being completely eliminated in the 1970's (City of Vancouver, 2002). In 1914 the Greater Vancouver Area decided Still Creek would be used as a rainwater runoff, thus due to increased urbanization with an estimated 68% of the catchment area made in impervious material, the unpredictable flows are the largest barriers to the creek being restored. This leads to high volume, high velocity flows over short periods of time, with the flow increasing many times the average annual flow during a heavy rainfall event, common in the Pacific Northwest region, known as a "flashy" system (City of Vancouver, 2002). However, due to recent restoration projects conducted by community groups, schools, and city and federal government bodies, Still Creek has been seen as a "success story" where urban rivers can co-exist with development and industry, symbolized by the return of salmon in 2012.

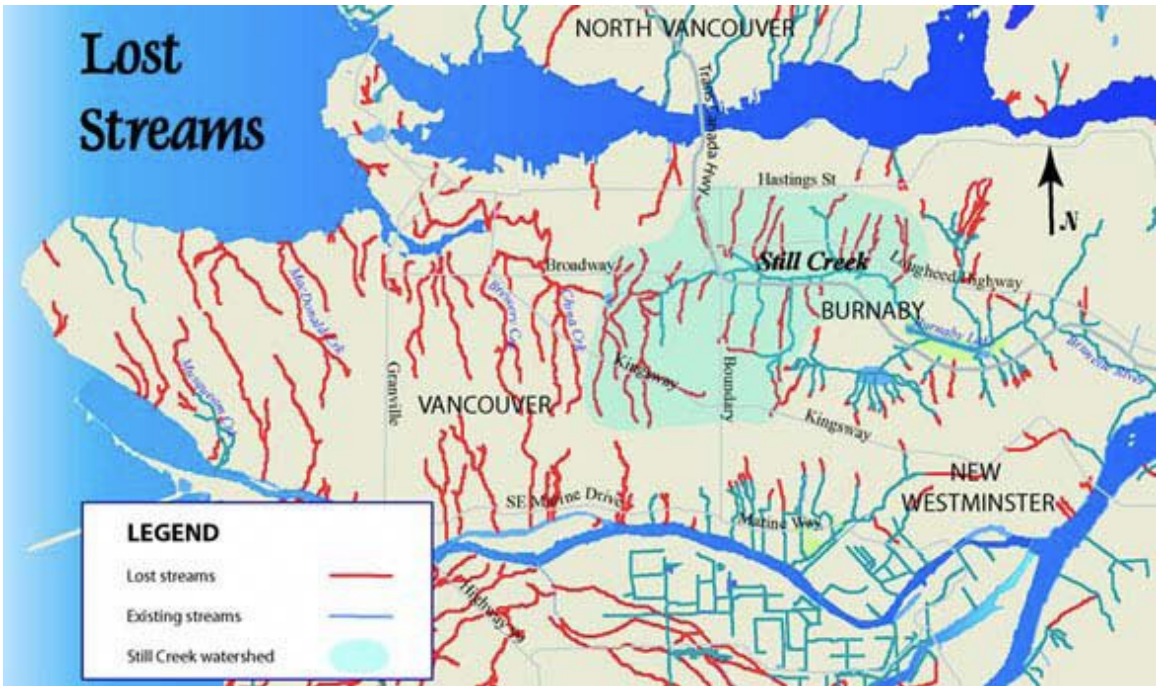


Figure [1]: Lost streams of Vancouver (Vancouver Street Stories, 2012)

The Restoration of Still Creek

The work on the restoration of Still Creek is not a recent phenomenon and actually begun through the work of river conservationist Mark Angelo in the 1970's. As Angelo reports, "being an advocate for the creek in the 1970's was a lonely exercise at that time" because people viewed the creek as a "lost cause" due to the heavy pollution and disuse of the waterway (March 8, 2017). Despite this view, he and other community groups continued to work towards reversing that pollution with the hope of a restored creek that could be used for recreational activities, community building, and of course, a habitat once again for salmon and other river creatures. In the mid 1990s, Carmen Rosen noticed that people living in the Renfrew Ravine area were afraid of going into the creek due to stories passed down from the 1950s of children getting illnesses from playing in the water, which lead to more and more garbage being thrown into the Ravine (March 13, 2017). To combat the fear,which clearly lead to increased pollution, she organized community activities like garbage clean-ups and an annual lantern festival to get people connected the the creek. As soon as people began to see the importance of having a river in their urban environment, more and more community organizations got involved, such as Evergreen, Silva Forest Foundation, and Still Moon Arts Society, founded by Carmen Rosen. Additional institutions also joined the restoration work such as the Rivers Institute at BCIT and SFU, and local high schools, while organizations such as the Vancouver Foundation helped fund the projects. Although the City of Burnaby, the City of Vancouver, and the Vancouver branch of the federal Department of Fisheries and Oceans had been monitoring the Creek prior to the active community engagement, more extensive studies and funding were sparked by the rise in community involvement. This also coincides with the larger trends towards improving urban environments and the City of Vancouver's 2008 "Greenest City 2020" initiative.

Thus in the wake of increased motivation and demand for Still Creek's restoration, numerous studies by city governments and community organizations were conducted. A report by Still Moon Arts Society (2010a), one of the main community organizations dedicated to restoring the creek has noted that the largest threats to the Renfrew Ravine include 1. Unpredictable flow rates from impervious surfaces surrounding the watershed, leading to erosion, channel morphology changes, increased sediment load, infilling, and flashy streams; 2. Pollutants accrued from runoff such as antifreeze and hydrocarbons, as well as pollutants from incorrect sewer connections; 3. Invasive species such as Himalayan Blackberry; and 4. Garbage dumping which destabilizes banks and leads to toxin runoff. All of these challenges are a direct result of the urbanization surrounding the stream. An additional challenge noted is that the runoff is often at a higher than normal temperature due to heat absorption in cement, leading to impacting the success of fish habitat even more than toxins (Still Creek, 2010b; GVRD, 2001). A 1998 Environment Canada study of the Brunette River Watershed included data collection from Still Creek, noting that of the watershed, Still Creek had the highest loadings for most metals, including eight trace metals which exceeded criteria for both aquatic life and recreation, as well as higher pollutant loads than Fraser River, for organochlorine pesticides were 10 times higher, and for polycuclic aromatic hyrdrocarbons (PAHs) were 2-3 times higher. The study noted the runoff correlation, that all contaminants increased as flow increased, including phosphorus and nitrogen, and E.coli and faecal coliform levels, while also raising concern of the urbanized Brunette River watershed contributing contaminants into the more healthy Fraser River (Environment Canada, 1998). Additional pollution entered to the Creek through unregistered sewage hook-ups in which many residents accidentally connected their sewage lines to the runoff lines that entered directly into the river (Still Moon Arts Society, 2010a).

Based on the above data, a 2002 City of Vancouver report outlined the main actions needed for restoring the creek and bringing back salmon (see Figure 2). The main concerns clearly surround the issue of urbanization, thus the need for solutions that work within the urbanized setting and also aim to alleviate the resulting issues. See Appendix A for a timeline of the events. Firstly, to address pollutants within the water, the riparian zone must be improved in order to filter pollutants, improve cooling of the water, provide natural habitat, and reducing stormwater volumes that enter the stream through evapotranspiration and storing ground water as deep as 150mm (City of Vancouver, 2002, 20). In 1999, only 26% of the daylighted portion of Still Creek had an intact riparian zone, with Renfrew Ravine being the only "significantly intact and relatively healthy" riparian area (ibid.). In light of this, community groups such as Still Moon Arts Society in conjunction with the City, have since pulled out invasive species and planted local plants as recommended by the report. These groups have also conducted garbage cleanup in the area, as plastic leaching can also contribute to pollutants in the water. Additionally, the organization has also been instrumental in engaging with people to use less pesticides in their yards and chemicals in their homes and for cleaning cars to reduce runoff (Rosen, personal communication, March 13, 2017). Secondly, as mentioned, Still Creek was designed to transfer stormwater since 1914, thus showing that infiltration has been reduced with increased and accelerated runoff through culverts and channelization, however this decision has lead to significant pollutants entering the stream directly. To manage this, the City of Vancouver proposed an Integrated Stormwater Management Plan for the Still Creek Watershed in 2006, with recommendations that continue to be carried out to reduce impervious surfaces, install stormwater retention-infiltration structures, and building swales (4). Furthermore, the City of

Vancouver has also been repairing sewage and stormwater lines in the areas around Still Creek such as Renfrew to prevent sewage entering the stream and reduce e.coliform (City of Vancouver, 2017).

Finally, in order to actually allow fish access which had been blocked off from culverts and covering the stream, fish ladders and baffles were built by community groups, City governments, and the Department of Fisheries and Oceans. One key change was when the Highway #1 that crosses Vancouver and Burnaby was being rebuilt, the TI Corporation reached out to the Department of Fisheries and Oceans and asked if there was anything they could do to ensure fish access, and then built baffles under the highway that allowed chum salmon to pass (Maurice Coulter-Boisvert, personal communication, March 8, 2017). Although water quality is still the biggest deterrent to successful salmon habitat and creek vitality, the continuation of the return of the salmon in 2012 clearly indicates that the creek is slowly being improved. Unfortunately, as of this past fall, there were only 15 salmon spawning, showing that much more work must be done for the long term health of the waterway. Further research on salmon habitat must be undertaken, as well as monitoring the sediment to understand how salmon affect transport which may lead to potential erosion or deposition and is less well-studied (Hassan, et al., 2007). Salmon tend to prefer to spawn on the edges of riffles and bars (Gottesfeld et al., 2004), so ensuring consistent sediment supply to maintain these structures is also important.

TABLE 4-4: POTENTIAL IMPROVEMENT OPPORTUNITIES

Subwatershed or Reach	Improvement Opportunities	Location
Still Creek		
	• Clean up garbage debris, provide signage/education on dumping and natural values of area, and improve trail access.	Renfrew Park
	• Flood management strategy	Kelly Court
	• Bank stabilization	Coronett to Boundary Road
	• Flood management strategy	Renfrew Park to Trout Lake
	• Improve culvert entrance condition	Boundary Road
	• Riffle weirs	between 29th and 22nd Aves.
	• Enhancement/revegetation of stream banks	Coronett to Boundary Road
	• Riffle weirs	Coronett to Boundary Road (in ravine)
	• Naturalize, increase complexity	Renfrew Park
	• Detention pond	Renfrew Park or Renfrew Ravine
	• Wetland	Renfrew Park
	• Wetland/pond - remove concrete flume	Kelly Court
	• Consider daylighting and land acquisition where possible as part of redevelopment opportunities and local planning processes	(e.g., Rupert to Coronett), d/s of Gilmore
	• Re-establish meander, reclaim floodplain (increase storage potential)	3800 Block to Gilmore
	• Stream enhancement and wetland	On North Branch below Gilmore
	• Flood management strategy	Renfrew to Sperling
	• Detention pond.	Westminster Ave to Douglas.
	• Stream enhancement and wetland	Beecher Creek to Sperling
	• Large scale in-line sediment pond or detention pond.	West of Sperling
	• Mitigate summer low DO levels - e.g., aeration, weirs, stream complexing	lower reaches
	• Greenway/Bikeway	along open sections and other areas as appropriate
	• Still Creek Trail / Greenway	full length of creek with some breaks and detours along roads (Fig. 25, BCIT report) and designated greenways in Vancouver
	• Improve fish passage	several locations identified in BCIT report (see Figs. 12-15, BCIT report)
	• Land Development Guidelines and policies	Open waterways in Vancouver
Beecher Creek		
	• Upgrade culverts and approaches for fish passage	@ Lougheed and @ Broadway

Figure [2] Potential Improvement Opportunities (Greater Vancouver Regional District, 2001, p. 38)

Data Analysis

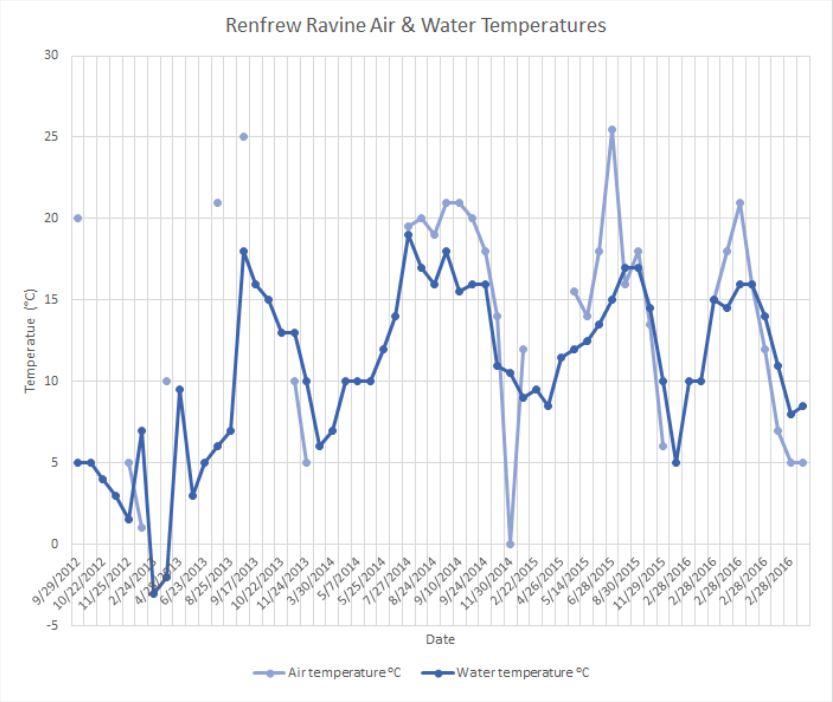


Figure [3]: Renfrew Ravine data collected by Evergreen

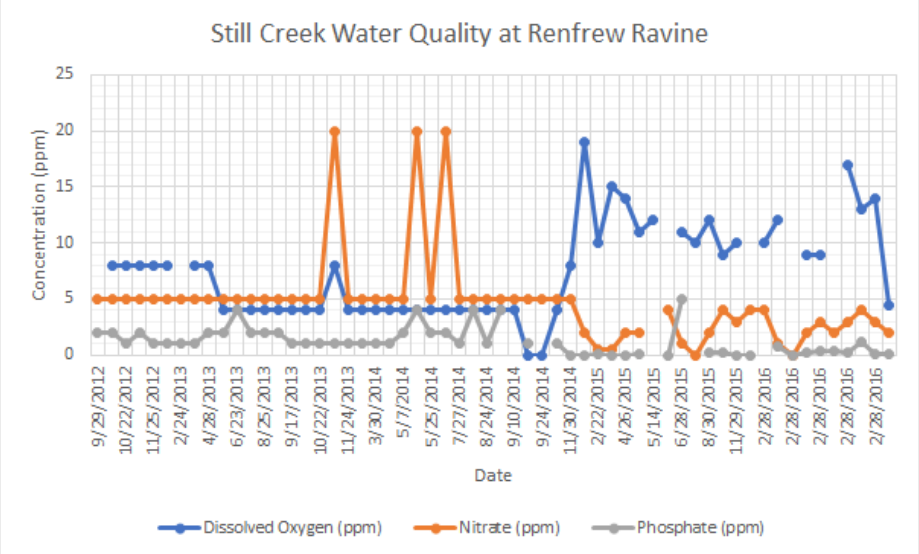


Figure [4]: Renfrew Ravine data collected by Evergreen

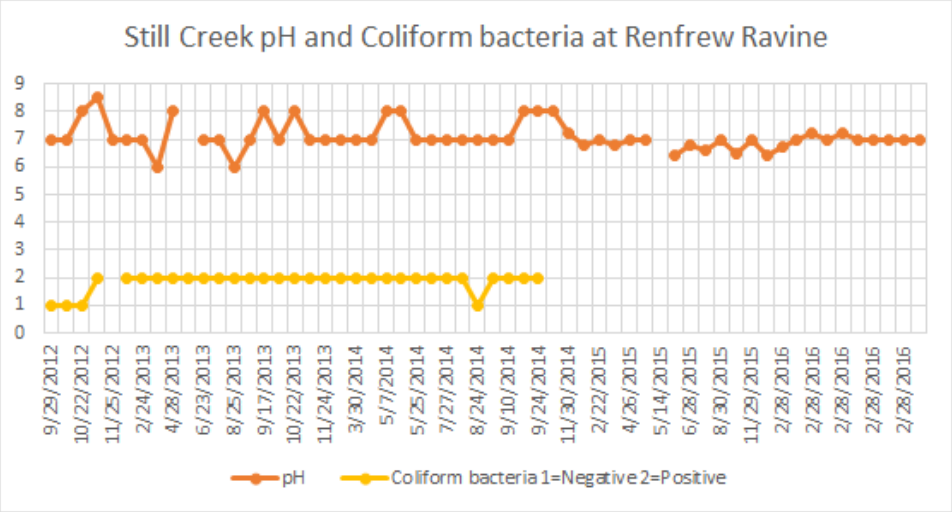


Figure [5]: Renfrew Ravine data collected by Evergreen

The data displayed in figures 3-5 was collected by citizen scientists as part of a community effort to monitor the Creek. The monitoring event takes place once a month and is organized by Evergreen, an NGO that promotes sustainable urban projects. (Evergreen, 2017) As mentioned previously, a common theme in river restoration literature is that monitoring of water quality is often limited after improvement efforts. (Wohl et al. 2015) This program is a valuable source of information because it is carried out regularly (in contrast to the testing done by consulting companies for a specific project). It is limited in that measurements are taken only roughly once a month. In addition, it appears that the presence of e. coliform is no longer tested for, despite the fact that it was present in the majority of tests.

Discussion

The Brunette Basin Watershed Plan was put together by GVRD Policy and Planning Department in 2001. The information that the GVRD used to create the plan includes the above history of watershed management , land use maps, peak and minimum flow information, water quality, and endangered and fish species living in the basin. All available information from previous reports and studies were taken into consideration to have a holistic understanding of the system. The Brunette Basin Watershed Plan (2001) is centered around three main premises: Impervious area reduction, stream corridor protection, and source control. Increasing permeability of the ground increases infiltration of water and decreases runoff. This is desirable not only for recharging groundwater, but also because it decreases the 'flashiness' of the stream. Stream corridors are valued for their ecosystem services, which include habitat, filtration of pollutants, and recreational value. The many trees in a stream corridor shade the water from direct radiation and the transpiration cools the area, preventing waste heat from the built environment from warming water temperatures.

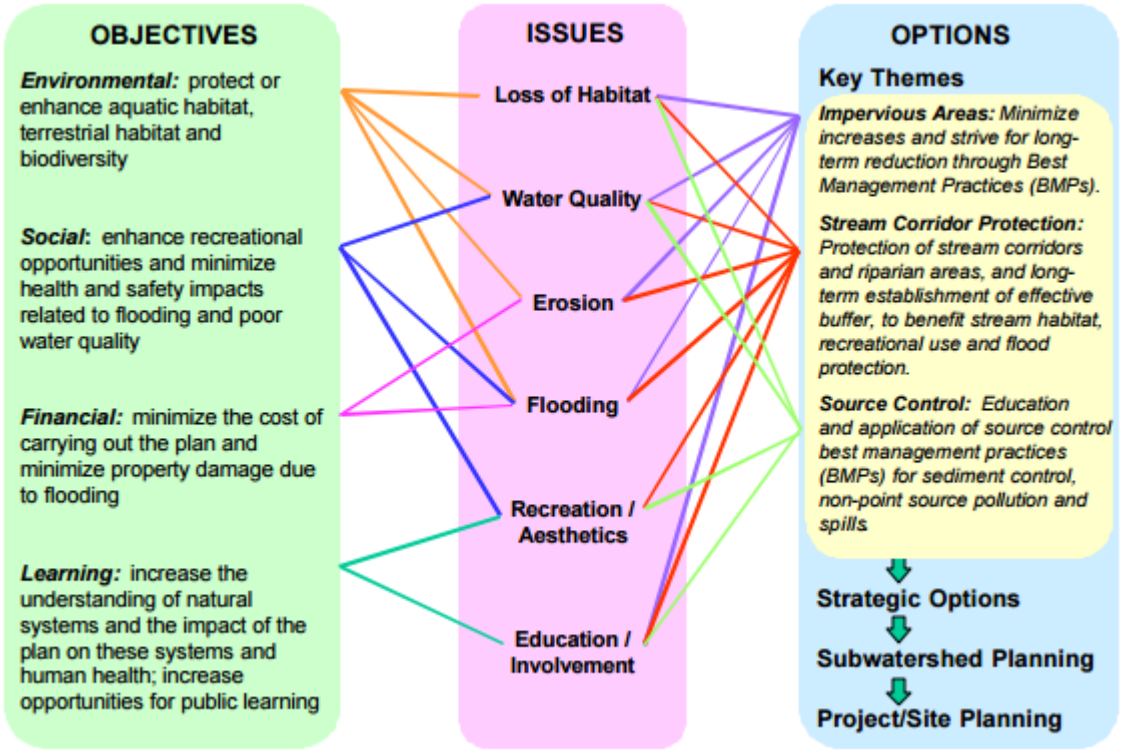


Figure [6]: Brunette Basin Watershed Plan (GVRD, 2001)

In 2002 the Still Creek Rehabilitation and Enhancement study was undertaken by the City of Vancouver. (City of Vancouver, 2002) The study took the information in the Brunette Watershed plan and developed 10 and 50 year action plans for 5 areas with different characteristics. However the five areas are all in the Granville Boundary industrial area (GBIA) and do not span the length of the creek. The study compiles a list of appropriate actions within each area within both timescales. It emphasizes cost effective "doable" projects that can engage the community and the different stakeholders. Although the study is spatially limited its flexibility is a strength. This flexibility addresses the challenge of having a watershed in two different municipalities with multiple local factors. The study makes recommendations for the improvement areas in the watershed outside the five areas. Impermeable infrastructure such as paved lanes, curbs, and gutters are recommended to be replaced at the end of their lifetimes with green alternatives such as roadside swales, retention ponds, and permeable paving material. (City of Vancouver, 2002) The other suggestions include building riparian zones, wetlands, paths, and places for people to interact with nature. (City of Vancouver, 2002)

Next Steps

Based on the previous data and analysis, the restoration of Still Creek is not finished, and as the literature suggests, the improvement of rivers is truly a long-term process. Firstly, monitoring by Evergreen and other non-governmental and governmental groups must continue to notice long-term trends and track changes or challenges to the river. In addition to hydrological data that are currently analyzed monthly, the health of the replanted riparian zone must also be monitored for

consistent nutrient flux and reproduction. Secondly, small-scale and large-scale infrastructure projects should be undertaken to improve the watershed. This includes more daylighting of the Creek, continuing the upgrades of sewage lines such as at Grandview (City of Vancouver, 2017), and building country lanes and swales to improve infiltration, reduce runoff, filter pollutants, and maintain a steady groundwater supply (City of Vancouver, 2006; Rosen, 2017). An artificial wetland and retention ponds by Renfrew Park Community Centre has also been proposed to achieve similar goals (City of Vancouver, 2005). Thirdly, community engagement through art projects, community events, citizen scientist data collection and other activities must continue to ensure that people see the value in the Creek as a natural system and to make sure governments continue their work as well. Finally, while most of the restoration of Still Creek has been undertaken using the third theory of restoration that includes ecological understandings, there still is a leaning towards the second theory of hydrogeomorphic engineering. This theory follows the assumption of "if we build it, they will come", with "they" being a specific species or ecosystem function (Palmer & Bernhardt, 2006). While salmon have returned for four years in a row to spawn, their numbers are low and more efforts must be taken in water quality and understanding sediment supply and transport to maintain their return.

Conclusions

As the literature shows, there are many challenges to river restoration. Competing interests between ecological needs and the needs of humans, challenges of incorporating multiple disciplines and community stakeholders, variables within the river and between rivers, and the fact that river restoration to a certain state is not possible given temporal and historical changes all complicate the desire to return rivers to a "natural" position. River restoration should focus on the improvement of the watershed's ability to provide clean water, healthy river species, and a habitat for plants and animals, though urban settings such as the one that Still Creek is in, provides many challenges. Despite this, the restoration at Still Creek can be considered a success, considering that the salmon have returned to spawn for four years in a row. Multiple stakeholders such as city planners, engineers, hydrologists, and community groups came together to study the Creek and find solutions, such as improving the riparian zone to filter pollutants, provide habitat, and decrease water temperature, decreasing pollution through improving sewage and stormwater connections and reducing chemical use in people's homes, and general education and restoration efforts involving the public. The involvement of the public is seen as especially important for community buy-in and to ensure the demand for improved river habitat and protection is maintained. As noted in the previous section, many steps must be taken to build on the restoration of the Creek, and much more analysis on other river restoration methods must be taken to share best practices and provide examples. Other research must be done on the impact of salmon on channel morphology and how urban expansion impacts hydrological processes such as rainfall, evapotranspiration, erosion, albedo, runoff, and nutrient fluxes.

Appendix A: A Brief History of Still Creek

A BRIEF HISTORY OF

STILL CREEK

Still Creek is part of the larger Brunette River Watershed which passes through Vancouver, Burnaby, and New Westminster before entering the Fraser River. In 2012 the Creek made history when salmon returned to spawn for the first time in 80 years.

1914
The Greater Vancouver Area designated Still Creek for stormwater runoff due to increased urbanization in the area.

1929
Still Creek envisioned as part of the "Parks and Pleasure Drive" system connecting Vancouver and Burnaby along the creek, however unfortunately due to stormwater management needs, parts of the creek were relocated and culverted to move water

1932
Collective memory as the last full salmon spawn in Still Creek

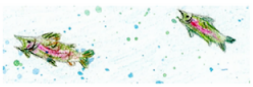
1950-1960
Buildings were built close to the creek's riparian zone which lead to flood risk, pollutants entering the creek, erosion, and decreased access to the water

1970-1980
Stormwater engineering philosophy began to shift towards the preservation of more "natural" systems, thus protecting the creek from being fully enclosed. Conservationists like Mark Angelo began calling for the creek's protection

LATE 1980S
Vancouver City Council began policies to protect the creek and daylight culverted areas

1996
Artist Carmen Rosen began community activities like lantern festivals and garbage clean-ups to engage peoople with Renfrew Ravine

2002
The Still Creek Rehabilitation and Enhancement Plan was endorsed by Vancouver City Council

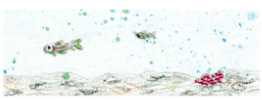


2006
The first City-lead improvement project was completed. Numerous activities such as riparian habitat improvement and building fish ladders have been conducted with community groups, governmental bodies, and schools

2012
Chum salmon return to spawn for the first time in 80 years

2016
15 salmon returned to spawn in Still Creek in the fall

2017 and beyond
Efforts continue towards protecting the creek, ensuring water quality, and engaging community through events and citizen scientist activities.



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