MEANDERING THROUGH CITIES:

ADAPTING RESTORATION FRAMEWORKS FOR URBAN STREAMS

By

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Abstract

Governments and community show an increasing commitment to restoring urban streams. Although restoration projects are becoming common, there is no integrated organization to oversee urban stream restoration in British Columbia and guidance for projects is limited. Projects tend to focus on restoring physical and ecological attributes to streams that may not be realistically achievable in a highly modified urban landscape. Social and institutional systems are often ignored even though experience tells us that they must be integrated into restoration plans to ensure the project has long-term success. There is a need for a framework to guide stream restoration that is adapted to the urban setting and that integrates environmental planning principles with ecological restoration principles.

My methods to develop such a framework included drawing upon my direct experience with an urban stream restoration project in East Vancouver, British Columbia. China Creek, the stream to be restored, was once a fast-flowing salmon stream. After urbanization of the watershed, it was eventually buried in the city's combined sewer system. I explored the preliminary ecological and social issues within the China Creek Watershed to determine the needs and challenges associated with daylighting or restoring China Creek. Once the challenges were identified, I reviewed an extensive number of stream restoration case studies to determine what elements practitioners consider critical to the success of a project.

In this report, I provide an overview of the physical, hydrological, ecological and community planning considerations that are key to urban stream restoration. I develop an adaptive, ecosystem-based planning framework to guide groups through the restoration process. The stages of the framework are (1) Feasibility, (2) Planning, (3) Design, (4) Implementation, and (5) Monitoring. The framework is designed to be adaptive and participatory. The framework incorporates seven elements that are critical to the success of urban stream restoration projects. These elements are: (1) an understanding of geomorphic and ecological processes, (2) a watershed perspective, (3) clear, well-developed goals and objectives, (4) early stakeholder and public involvement, (5) political support, (6) effective communication and education, and (7) project monitoring and evaluation.

The framework may be used to evaluate prospective restoration projects, for guiding the selection of realistic restoration objectives, and for guiding tangible design and implementation of stream restoration projects to achieve their desired functions in an urban setting.

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

Urban streams are arguably the most extensively degraded and disturbed aquatic systems in North America. Deltas, estuaries, riverbanks and floodplains have typically been used for building sites, transportation corridors and waste disposal. Urban development planning has assigned a low priority to protecting productive fisheries and stream habitats, and British Columbia is no exception in this regard (Millar et al. 1997).

Roads, sewers and water lines have been constructed in, along, and across stream channels. Wetlands and stream tributaries have been filled in. Culverts have been designed and installed without regard to fish passage. Pollutants and sediment are routinely discharged into streams. Engineers have "improved" drainage efficiency by removing vegetation, straightening rivers and encasing them in concrete. Floodplains have been isolated by dikes and containment walls, or paved over and completely lost. Urban streams have been relentlessly caged in underground pipes to quickly convey water away from developed areas, destroying ecosystems and human connections to the stream.

As our rivers and streams degrade, we are realizing not only the importance of the ecological functions provided by river systems, but also the historical and cultural values associated with them (Jones and Battaglia 1989, Beaulieu 1990, Roseland 1997). In British Columbia, environmental organizations and concerned citizens have designated urban streams as a priority for protection and restoration[1] (Outdoor Recreation Council BC 1998). Interest in restoring urban streams is expanding nationally and internationally, as indicated by increasing numbers of case studies, published papers, technology exchanges, research projects and symposia. The drive to protect and restore urban streams is part of a bigger movement to improve the liveability of our urban communities.

This movement to 'green the city' is known variously as urban ecology, sustainable cities or ecological cities (Newman 1996). Worldwide, we are beginning to establish strategies for working toward more sustainable urban communities (Beatley 1999, Kaplan et al. 1998, Roseland 1997, O'Meara 1999, Roseland 1998, President's Council on Sustainable

[1] For the purpose of this paper, I have consistently used the widely adopted term "restoration" to define the whole continuum of activities described by the National Research Council (1992). *Restoration* returns an ecosystem to a close approximation of its condition before it was disturbed. *Rehabilitation* improves a system to a 'good working order'. *Management* manipulates a system to ensure maintenance of one or a few functions.

Development 1997, BC Round Table on the Environment and the Economy 1994, Urban Land Institute 1998). A common criterion used to assess urban sustainability is natural habitat within the urban environment. In British Columbia, the Round Table on the Environment and the Economy (1994) recommended that one method for moving toward urban sustainability was to implement programs to protect, reclaim and rehabilitate streams in urban areas.

Driven by the urban sustainability movement, and the decline of salmon populations on the west coast, governments in British Columbia are beginning to value urban streams. Federal, provincial and municipal governments have increased their commitment to improving fish habitat in our urban streams. Initiatives such as the Urban Salmon Habitat Program, the Habitat Conservation and Stewardship Program, Pacific Stream Keepers, the Salmonid Enhancement Program, Fisheries Renewal BC and the Salmon Habitat Restoration Program are funding and supporting urban stream restoration and stream stewardship projects throughout British Columbia.

This renewed focus on urban streams by all levels of government supports citizens' actions toward protecting and restoring urban streams. Recently there has been an explosion of stream or watershed organizations that are interested in protecting and restoring local streams (Houck 1996, Botelho 1998, Hurley 1998, Riley 1998, Romaine and Romaine 2000). The majority of these organizations are community-based watershed stewardship groups that are taking responsibility and caring for their local streams. Although these groups have as their goal to restore or protect a stream, they may not always know how to go about it, or even if restoration is really an achievable goal.

In British Columbia, community groups seeking to plan and implement an urban stream restoration project typically have little guidance. Moreover, resources and relevant literature are not easily accessible and often very technical. In many cases, this results in poorly planned and designed projects for stream restoration that have insignificant ecological benefits, or worse that actually create additional problems for the stream (Hurley 1998). Also, funding agencies that allocate money for projects are rarely trained or experienced in matters of stream restoration. Projects are typically chosen on a consensus basis without a common framework to evaluate which projects will actually achieve their desired objectives in the real-world urban landscape. A framework to guide groups through the important processes of stream restoration would improve project planning and help funding agencies to develop criteria that highlight the most feasible projects.

Many guidebooks and research papers illustrate the physical and ecological principles of stream restoration (e.g., Cowx and Welcomme 1998, Newbury and Gaboury 1994, Newbury et al. 1998, Williams et al. 1997, Ontario Ministry of Natural Resources 1994, Slaney and Zaldokas 1997, Federal Interagency Stream Restoration Working Group 1998). Although such documents provide theory that is key to ecologically based urban stream restoration projects, their focus is primarily on design techniques, with no detailed discussions of how to integrate urban constraints into restoration approaches.

A number of ecological restoration frameworks have been proposed (e.g., Hobbs and Norton 1996, Ebersole et al. 1997). Although they describe key processes important for ecological stream restoration, available ecological restoration frameworks are not specific to restoration projects in a highly modified urban setting. Moreover, these frameworks focus primarily on biological systems. Given that the urban landscape is a combination of dynamic, overlapping social systems, ecological systems and management or institutional systems (Quayle 1992), these frameworks are inadequate for addressing the multidisciplinary challenges of urban stream restoration.

Wyant and others (1995) recognized the need for an environmental restoration framework that incorporates both ecological and socio-economic perspectives. They called for the development of a decision framework to aid in selecting ecologically and economically robust restoration techniques on a site-specific basis. In response to this need, Pastorok and others (1997) presented an ecological planning process that could provide the ecological portion of such a framework. This ecological planning framework identifies eleven primary steps for environmental restoration projects. Unfortunately, it does not make reference to any socio-economic components.

Despite the absence of integrated stream restoration frameworks, integrated ecosystem approaches for environmental planning have been discussed (Slocombe 1993, and Lessard 1998) that are extremely relevant to urban stream restoration. The ecosystem approach emphasizes system elements and relationships which link people, societies, economies and environment. The ecosystem approach stresses the value of holistic, comprehensive or integrated approaches, in which cross-sectoral and interagency management and cooperation are essential. The ecosystem approach has been viewed as one means for achieving sustainable development and urban stewardship (Mitchell and Shrubsole 1994).

The principles required to address the challenges of urban stream restoration are well developed. However, they are spread amongst the literature of various academic disciplines, from fluvial geomorphology to urban planning. The challenge is to identify the most important principles and integrate them in the development of a useful framework to effectively guide urban stream restoration projects.

1.1 Problem Statement

Governments and community show an increasing commitment to restoring urban streams. Although restoration projects are becoming common, there is no organization to oversee urban stream restoration in British Columbia and guidance for projects is limited. Projects tend to focus on restoring physical and ecological attributes to streams that may not be realistically achievable in a highly modified urban landscape. Social and institutional systems are often ignored even though experience tells us that they must be integrated into restoration plans to ensure the project has long-term success. There is a need for a framework to guide stream restoration that is adapted to the urban setting and that integrates environmental planning principles with ecological restoration principles.

1.2 Purpose of the Research

The goal of my research is to develop a framework to guide urban stream restoration projects. I have three objectives to achieve this goal. They are:

(1) to draw upon my direct experience with an urban stream restoration project to highlight the needs and challenges of urban stream restoration projects;

(2) to review the urban stream restoration literature and case studies to determine what elements are most important for successful projects; and

(3) to develop an adaptive and community-based framework for restoring urban streams that integrates fundamental ecological principles of stream restoration with environmental and community planning principles.

The framework may be used to evaluate prospective restoration projects, for guiding the selection of realistic restoration objectives, and for guiding tangible design and implementation of stream restoration projects to achieve their desired functions in an urban setting. The framework is geared toward community groups and municipalities that are interested in engaging in stream restoration projects, and also toward funding agencies that must decide what restoration projects are worthy of investment.

1.3 Methods and Report Structure

I have used this report to develop a framework for urban stream restoration based on a combination of direct participation in stream restoration projects, and a review of general literature on worldwide approaches to stream restoration and environmental planning.

Chapter 2 is a case study of an urban stream restoration project that I was personally involved in scoping. I researched the past and present conditions of the urban watershed to determine the feasibility of daylighting[2] a lost stream named China Creek on Vancouver's east side (Brown 1999). Local organizations and government agencies provided input to the project, which allowed me to establish a preliminary understanding of the obvious issues in the China Creek watershed. I identified the physical watershed conditions and the social and institutional issues that create challenges for daylighting the creek. Most of these challenges are similar to challenges faced in many other urban stream restoration projects.

Chapter 3 is an overview of the physical, hydrological, ecological and planning considerations that are key to urban stream restoration. I performed a qualitative exploration of the barriers and challenges of implementing stream restoration projects in urban settings. From an extensive literature review of stream restoration case studies, I identified seven elements that have been deemed 'essential' in implementing successful stream restoration projects in urban settings. I qualitatively analysed these case studies to determine what problems they have solved, and whether new problems were created in the process.

This approach enabled me to integrate the essential elements into a framework that I designed to address the needs and challenges of urban stream restoration projects. Chapter 4 presents the integrated framework, describes each phase, and discusses the processes most important for each phase. For select processes, I suggest tools that will help groups overcome challenges.

[2] To "daylight" a stream is to dig up a culverted water source and reconnect it to its surrounding land surface in a restored, natural channel.

2.0 China Creek: A Restoration Case Study

China Creek is a worst-case example of a stream in need of restoration. The stream has been flowing underground for almost 50 years and its watershed is fully urbanized and highly impervious. This case study serves to identify the unique needs and challenges associated with restoring urban streams.

2.1 The Historic Watershed and Creek

China Creek was once one of the largest drainages in Vancouver, British Columbia (Proctor 1989). This historic watershed drained an area of approximately 12 km^2 (Figure 1). The historic bankfull[3] discharge of China Creek was approximately 2.5 m^3/s and the average width of the stream was approximately 7 m (see Appendix 1 for estimation methods).

Trout Lake, the headwaters of China Creek, once had three streams flowing into it, the largest being Gladstone Creek (Proctor 1989). The area around Trout Lake was a peat bog surrounded by a hemlock forest. In 1926, the land around Trout Lake became the property of the Vancouver Parks Board and the water level of the lake was lowered to connect with the sewer and to create safe swimming beaches (Trout Lake Restoration Committee 1995). In the 1930s and 40s frequent peat fires burned around the Trout Lake. The peat was eventually mined from the bog surrounding the Lake.

China Creek flowed out of the north end of Trout Lake and emptied into False Creek, an ocean inlet originally composed of tidal flats, marshy shores and forested lands. China Creek was a productive salmon stream in the early 1900s and local residents remember fishing for two and three-pound rainbow trout in the big pools of the creek (Proctor 1989).

As East Vancouver grew, the watershed was deforested and paved. In the early 1900s, with the advent of the railway, the False Creek tidal flats were filled in using excavations from the Grandview Cut. The site became home to a wide variety of heavy industries including steel fabrication, incineration, asphalt production, shipbuilding, metal finishing and storage of wood, fuel and coal.

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[3] The bankfull discharge or flow is often referred to as the channel-forming discharge and it usually has a return period or recurrence interval of 1.2 to 2 years in natural channels (Dunne and Leopold 1978).

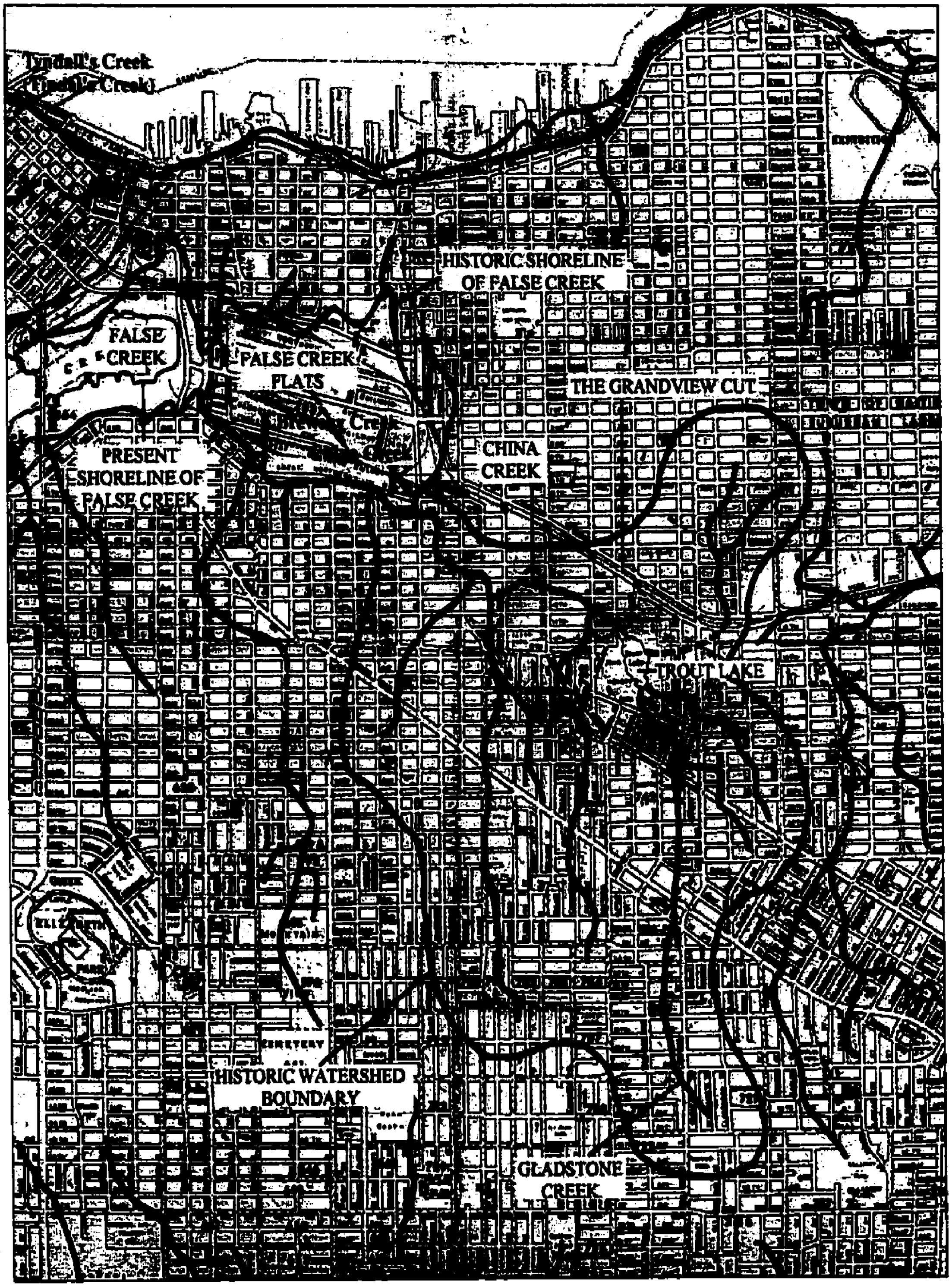

Figure 1: The natural drainage of China Creek before the city was developed around it. Adapted from Proctor (1989)

China Creek dwindled in size as its tributaries were filled in and the sewage system was expanded. The local residents began to see the creek as a menace to health as it became sluggish and polluted (Proctor 1989). The creek was finally confined to a large sewer pipe in 1952; it now drains into the Greater Vancouver Regional District's combined sewer and storm system.

2.2 Present Watershed Conditions

The China Creek watershed has dramatically changed since the early 1900s. The entire area has been developed and land use within the watershed is primarily residential and industrial. A combined sewer system[4] now drains most of the watershed, which has approximately 70% impervious cover (Stewart 1998).

2.2.1 Headwaters

The 26 ha of parkland that surrounds Trout Lake support a variety of recreational uses. Unfortunately the original ecosystem has been modified and degraded by human activity. With the exception of a remnant patch of peat bog on the east side of the lake, most of the naturally occurring vegetation has been replaced with non-native plant species and manicured lawns. The designated swimming area is often closed for periods every summer due to high counts of fecal coliform bacteria and high turbidity levels. The high turbidity is a result of elevated nutrient and algae levels and large concentrations of suspended sediment (EBA 1992). Lake levels fluctuate seasonally and have been slowly decreasing since the 1930s.

2.2.2 Receiving Waters and Surrounding Area

The mouth of China Creek historically flowed into False Creek at 7th Avenue and Glen Drive however; these receiving waters were filled in and are now referred to as the False Creek Flats (Figure 1). Given these present conditions, the receiving waters of a daylighted China Creek would become the south-eastern shore of False Creek.

Presently, the south-east shoreline of False Creek is primarily industrial, with the exception of the eastern most shore which is home to Vancouver's Science World. The

[4] Combined sewers transport wastewater and stormwater runoff in the same pipe.

Southeast False Creek industrial site has been proposed for re-development into a model sustainable residential community (Sheltair Group Inc. 1998). The area south of the rail lands on the False Creek Flats is planned for development as a high amenity industrial area to attract high tech industries.

The water quality of False Creek is a concern to local residents and environmental organizations as, on average, False Creek receives combined sewer overflows about 45 times annually (GVRD 1999). Combined sewer overflow, in conjunction with shoreline development and heavy industrial use, has degraded the habitat and water quality of False Creek.

2.2.3 Existing Green Space

Existing green, or open space between Trout Lake and False Creek is minimal. The largest contiguous patch of green space is the Grandview Cut, situated just one block north of Trout Lake's park perimeter. The Grandview Cut is an artificially excavated, steep-sided ravine that runs east-west to the False Creek Flats. The Cut averages approximately 50 m across. A rail line owned by the Burlington Northern Railway (BNR) occupies approximately 10 m in the bottom of the ravine. In 1990, the City purchased the north and south banks of the Grandview Cut from the BNR who still retains ownership of the ravine bottom.

Since 1910, the Grandview Cut has become an important local ecosystem. It is the largest "wild" corridor in East Vancouver and is home to many species of trees, shrubs, herbs, grasses, birds and mammals that are not found in the surrounding urban area (Wu and Flannery 1996). The Grandview Cut is locally important for biodiversity conservation, given the lack of other semi-wild green spaces within East Vancouver.

The City of Vancouver originally identified the Grandview Cut as a potential site for a greenway. However, the city has just recently approved plans to extend the Skytrain, which will operate on the north bank of the ravine, "above" the railway.

The other green space in the historic China Creek watershed is China Creek Park – a small neighbourhood park the size of two city blocks. This site is significant, as this was the original mouth of China Creek, where it entered False Creek, before the tidal flats were filled in and developed.

2.3 The Impetus for Restoration

Various individuals, organizations and government agencies have expressed interest in restoring China Creek and other lost streams in the city of Vancouver. Community groups such as the Trout Lake Restoration Committee, Friends of False Creek, the Community Renewal of Economic and Environmental Culture Society (CREEKS), and the Steelhead Society of BC would like to make ecological improvements to the urban landscape and create educational and stewardship opportunities within the community.

The City of Vancouver's Engineering Department became interested in daylighting streams as a solution to stormwater management problems that have been present in Vancouver for many years. The City is slowly replacing the aging sewer infrastructure – a time consuming and costly process. In the meantime, combined sewers often overflow into False Creek and the Burrard Inlet when high runoff volumes occur. The Engineering Department recognizes that one potential benefit of daylighting China Creek would be to reduce the amount of stormwater entering the combined sewers, and ultimately reduce both the combined sewer overflows and the volume of sewage being treated at the wastewater treatment plant.

The City of Vancouver's Planning Department has proposed a system of greenways throughout the city (City of Vancouver 1995). One of these proposed greenways links Trout Lake to False Creek. Although the city's initiatives to date have largely ignored opportunities to restore ecological systems, a number of studies provided to the City of Vancouver have articulated visions of ecological greenway design (e.g. Quayle 1992, and Stewart 1998).

A cursory look at the China Creek watershed identified many different groups with interests or objectives that can be directly linked to restoring China Creek (Brown 1999). It is evident, however, that restoring China Creek is much more complicated than designing a stream with natural characteristics to provide for a healthy, aquatic ecosystem. The mix of ecological systems, social systems and management or institutional systems creates challenges for stream restoration, and at the same time creates exciting opportunities not often found outside of an urban setting.

2.4 Constraints for Restoring China Creek

To restore China Creek will be a difficult task, especially given the present watershed conditions. Equally daunting, however, are the social and economic complexities that can make restoring an urban stream extremely challenging. It is instructive to review the physical, ecological, social and economic considerations that must be addressed to restore China Creek. This process helps to identify needs and challenges for urban stream restoration projects in general. Important considerations for restoring China Creek include:

- No existing open channels – all historic streams are flowing in combined sewer pipes
- No existing riparian corridor
- Watershed is highly impervious
- Watershed topography has been altered
- Route selection opportunities are limited
- Land acquisition is complicated – all the land is developed and most is privately owned
- Space will be limited, therefore incorporating a floodplain, graded bank slopes and lateral migration into stream design may not be possible
- High probability that soil is contaminated in areas where stream could be daylighted
- Stormwater runoff will carry pollutants from paved surfaces and roof-tops
- Existing infrastructure such as train tracks and utility lines are situated in the Grandview Cut
- Impending construction of the Skytrain in the Grandview Cut
- Stream crossings under major intersections are potential fish barriers
- Existing infrastructure could make costs prohibitive; can the long-term benefits outweigh the costs?
- Who will pay the restoration costs and ongoing maintenance costs?
- Existing policies and legislation may conflict with restoration goals
- Regulatory duties are spread amongst at least three levels of government and amongst many different agencies and groups within those three levels
- Potential issues of public safety from flooding, swift currents and water quality
- The general public is not aware of China Creek's history

- The project will take a long time to plan and get approvals for and will require a long-term commitment to realize
- Who will lead the process?
- Conflicting objectives among interested parties
- Information and expertise is scattered among various government agencies, individuals and community groups
- Coordinating all the players will be time-consuming and challenging
- The City of Vancouver has a traditional approach to engineering and planning and departments often work in isolation from each other

2.5 Opportunities Identified

Generating momentum for an urban stream project is easier if restoration plans are coordinated with other community plans and processes or if they tie into urban or community themes within the watershed. Roseland (1998) identifies urban streams as vehicles for education about local history and ecology, and places for rest, recreation, public art, neighbourhood beautification and community activism. The restoration of China Creek could be a catalyst for community activism and capacity building. Incorporating the following ideas into the restoration plan could generate community involvement and enthusiasm and help to meet the objectives of many diverse organizations, individuals and agencies within the watershed:

- Create a greenway beside China Creek for pedestrians and cyclists
- Improve public access to the urban waterfront at False Creek
- Restore the shoreline along False Creek where China Creek emerges
- Create an educational program with Science World to demonstrate the restored shoreline and creek
- Provide historical and cultural links to the rest of the city by overlapping the restoration route with a proposed heritage pathway (Alexander and McKenzie 1999)
- Provide opportunities for public art along the route of China Creek
- Restore the wetland ecology of Trout Lake
- Utilize Trout Lake for stormwater filtration and detention
- Formalize education programs with neighbouring schools or community centres

- Incorporate the daylighted stream into the designs for the sustainable community at Southeast False Creek
- Raise public awareness of lost urban streams in Vancouver
- Create sustainable stormwater management programs throughout the watershed
- Reduce basement flood damage in neighbourhoods where China Creek has been buried
- Improve water quality in False Creek
- Reduce the volume of sewage treated at the Iona wastewater treatment plant
- Daylight Gladstone Creek in Trout Lake Park as a daylighting demonstration site
- Daylight a small section of China Creek in China Creek Park, the original location of the creek's mouth
- Encourage information sharing between government agencies, community groups, environmental organizations, businesses and the general public
- Encourage stewardship by educating and involving neighbourhoods in the restoration process

2.6 Restoration Possibilities

As illustrated by the preliminary list of constraints generated in section 2.4, restoring China Creek will be a major challenge. However, many alternative restoration possibilities exist, each one with different constraints and different opportunities. For illustrative purposes I depicted the constraints and opportunities for four potential components of a restoration plan to daylight China Creek (Table 1). The potential restoration components are to (1) daylight China Creek as a stream that supports a viable fish population, (2) daylight China Creek as a stream that conveys stormwater to False Creek as its primary purpose and does not necessarily support fish populations, (3) flood Trout Lake to store water and restore its wetland ecology, and (4) daylight Gladstone Creek, a tributary of China Creek.

Table 1 illustrates that the restoration components that optimize the greatest number of opportunities with the fewest constraints are to daylight Gladstone Creek and to flood Trout Lake. These projects have a smaller scope, require less land, and are therefore faced with fewer challenges than daylighting the entire length of China Creek. Naturally, due to the smaller scope of these restoration components, they have fewer opportunities associated with them.

Table 1: Constraints and opportunities tested against four potential restoration components of daylighting China Creek.

	Potential Components of China Creek Restoration Plan			
	(1)	(2)	(3)	(4)
Constraints for achieving restoration component **× = constraint exists for particular component**	**Restore China Creek to support fish**	**Restore China Creek to transport stormwater**	**Flood Trout Lake**	**Daylight Gladstone Creek**
Existing streams are flowing in sewers	×	×	×	×
No existing riparian corridor	×	×		×
Watershed is highly impervious	×		×	×
Watershed topography has been altered	×	×		
Route selection opportunities limited	×	×		
Complicated land acquisition	×	×		
Space limited for floodplain and lateral channel migration	×			
Contaminated soil	×			
Pollutants in stormwater	×		×	×
Existing infrastructure in Grandview Cut	×	×		
Stream crossings potential fish barriers	×			
High costs due to urban infrastructure	×	×		
High maintenance costs	×	×	×	
Conflicts with existing policies or legislation	×	×		×
Potential safety issues	×	×	×	×
Public education necessary	×	×	×	×
Long timeframe to plan project	×	×		
Conflicting objectives among stakeholders	×	×	×	×
Opportunities associated with restoration component **✓ = opportunity is achievable**				
Continuous greenway	✓	✓		
Improve public access to waterfront	✓	✓		
Restore shoreline of False Creek at mouth of China Creek	✓	✓		
Create educational program with Science World	✓	✓		
Provide link to heritage pathway	✓	✓		
Public art opportunities	✓	✓	✓	✓

Restore the wetland ecology of Trout Lake	✓		✓	✓
Create educational programs with neighbourhood schools	✓	✓	✓	✓
Incorporate daylighted stream into sustainable community at S.E. False Creek	✓	✓		
Raise public awareness for lost streams in Vancouver	✓	✓		✓
Create stormwater management programs	✓	✓	✓	✓
Reduce basement flood damage	✓	✓		
Improve water quality in False Creek	✓	✓		
Reduce volume of sewage to wastewater treatment plant	✓	✓		
Simplified project for demonstration			✓	✓
Engender stewardship	✓	✓		✓
Encourage information sharing	✓	✓	✓	✓

After a brief analysis of the challenges or constraints facing the restoration project, it is evident the majority of the constraints are either biophysical issues (e.g. altered hydrology, fish passage at culverts) or socio-economic issues (e.g. high costs given urban infrastructure, Skytrain development in Grandview Cut). The major challenge becomes developing a plan to restore limited function to China Creek that addresses these constraints and makes the most of the opportunities associated with the restoration features.

Integrating functioning ecosystems into urban development is a challenge. The biophysical impacts of urbanization combined with the human dimension create many multifaceted problems. Therefore, solving these problems requires unique and interdisciplinary solutions that foster coordination and cooperation of all those involved – municipalities, stewardship groups, industrial users, local businesses, students, ratepayers, educational institutions, and other levels of government – to bring their expertise and concerns to the table. Urban stream restoration projects become planning projects that incorporate ecological principles of stream restoration into a socio-economically driven process.

3.0 Ecological and Planning Considerations for Urban Stream Restoration

Urban development imposes a variety of watershed changes that profoundly affect river ecosystem functions. Physical changes to the watershed are reflected directly or indirectly as change in the aquatic ecosystem. Unfortunately, making this link is not always common practice and, often, urban stream restoration projects do not take into account altered watershed conditions.

The common cycle of changes that happen to streams during land development and urbanization forms the critical framework for the urban stream restorationist (Riley 1998). We cannot diagnose a stream's problems and prescribe a solution for rehabilitation without: 1) understanding what parts of the whole watershed are contributing to the problems and 2) understanding natural river characteristics so that we can recognize the changing dynamics of streams and work with these natural attributes.

3.1 General Attributes of Alluvial River Systems

There has been a progressive realization that rivers must be managed by mimicking natural geomorphic processes, as they are responsible for determining the structure and function of river ecosystems (Nunnally 1985, Newbury and Gaboury 1993, McBain and Trush 1997, Kellerhals and Miles 1996). Therefore, before attempting to restore a river, it is crucial to first recognize the fluvial geomorphic[5] processes that once created and maintained dynamic river morphology, and next establish plant and animal dependencies in relation to these processes (McBain and Trush 1997).

Stream morphology is the result of an integrative process of mutually adjusting variables. A disturbance that creates a change in one variable sets up a set of concurrent changes in the others resulting in altered channel patterns.

River systems have common relationships between channel form and fluvial processes, as well as common physical and biological characteristics. Many authors, such as Leopold et al. (1964), Hynes (1970), Dunne and Leopold (1978), Bescheta and Platts (1986), Change (1988), Calow and Petts (1992), Newbury and Gaboury (1993), and Kellerhals and Miles

[5] Fluvial geomorphology is the science of earth forms produced by the action of flowing water.

(1996) have documented the biological and physical relationships between the aquatic ecosystem and its watershed.

McBain and Trush (1997) have identified a set of ten quantitative physical and biological attributes for assessing integrity in alluvial[6] river ecosystems. These attributes (Table 2) can guide a preliminary assessment of river ecosystem integrity and selection of appropriate restoration strategies for altered alluvial river systems.

Table 2: General Attributes of Alluvial River Ecosystems

No.1 ***Spatially complex channel morphology:*** No single segment of channel bed provides habitat for all species, but the sum of channel segments provides high-quality habitat for native species. A wide range of structurally complex physical environments supports diverse and productive biological communities.

No.2 ***Flows and water quality are predictably variable*:** Inter-annual and seasonal flow regimes are broadly predictable, but specific flow magnitudes, timing, durations, and frequencies are unpredictable due to runoff patterns produced by storms and droughts. Seasonal water quality characteristics, especially water temperature, turbidity, and suspended sediment concentration fluctuate seasonally. This temporal "predictable unpredictability" is the foundation for river ecosystem integrity.

No.3 ***Frequently mobilized channel bed surface:*** Channel bed framework particles of coarse alluvial surfaces are mobilized by the bankfull discharge, which on average occurs every 1-2 years.

No.4 ***Periodic scour and fill:*** Alternate bars are scoured deeper than their coarse surface layers by floods exceeding 3- to 5-year annual maximum flood recurrences. This scour is typically accompanied by re-deposition, such that net change in channel bed topography following a scouring flood is minimal.

No.5 ***Balanced fine and coarse sediment:*** River reaches export fine and coarse sediment at rates approximately equal to sediment inputs. The amount and mode of sediment storage within a given river reach fluctuate, but also sustain channel morphology in dynamic quasi-equilibrium when averaged over many years. A balanced coarse sediment budget implies bedload continuity; most particle sizes of the channel bed must be transported through the river reach.

[6] An alluvial river is free to adjust dimensions such as size, shape, pattern, and slope in response to change and flow through the channel. The bed and banks of an alluvial river are composed of material transported by the river under present flow conditions.

No.6 ***Periodic channel migration:*** The channel migrates at variable rates and establishes meander wavelengths consistent with regional rivers having similar flow regimes, valley slopes, confinement, sediment supply and sediment calibre.

No.7 ***A functional floodplain***: On average, floodplains are inundated once annually by high flows equalling or exceeding bankfull stage. Lower terraces are inundated by less frequent floods. These floods also deposit finer sediment onto the floodplain and low terraces.

No.8 ***Infrequent channel resetting floods***: Single large floods (e.g., exceeding 10-yr to 20-yr recurrences) cause channel avulsions, rejuvenation of mature riparian stands to early-successional stages, side channel formation and maintenance, and create off-channel wetlands (e.g., oxbows). Resetting floods are as critical for creating and maintaining channel complexity as lesser magnitude floods.

No.9 ***Self-sustaining plant communities:*** Natural woody riparian plant establishment and mortality, based on species life history strategies, culminate in early- and late-succession stand structures and species diversities (canopy and understory) characteristic of self-sustaining riparian communities common to pristine regional river corridors.

No.10 ***Naturally fluctuating groundwater table:*** Groundwater fluctuations in floodplains, terraces, sloughs, and adjacent wetlands occur inter-annually and seasonally.

These attributes prescribe process and form as quantitative restoration goals. The authors' intention is to provide managers with performance criteria for adaptive management monitoring when prescribing annual flow regimes for regulated river systems (McBain and Trush 1997). The table of alluvial river ecosystem attributes demonstrates the challenges of restoring ecosystem function to a physically modified urban watershed.

To successfully restore any stream, we must understand the principal characteristics that are necessary to maintain a high level of stream quality or ecological integrity. Restoration in an urban setting involves identification of the symptoms of stream imbalance or non-equilibrium, discovery of the causes of the imbalances, and then attempts to correct, or at the very least compensate for, the causes.

3.2 The Effects of Urbanization on Streams

The effects of watershed urbanization on streams are well documented (Leopold, 1968, Hammer 1972, Hollis 1975, MacKenzie 1987, Klein 1979, Arnold et al. 1982, Booth 1990 &1991, Schueler 1995b). Research has revealed that urban development has a profound impact on the hydrology, morphology, water quality, and biodiversity of urban streams. The intensity of the impacts vary, yet are typically a function of the intensity of urbanization (Scheuler 1995b).

3.2.1 Changes in Stream Hydrology

Urbanization results in physical changes to the watershed such as: an increase in impervious surfaces, loss of native vegetation and the canopy of trees, construction of roads and drains to collect stormwater runoff, re-graded ground surfaces, soil compaction, the destruction of wetland areas, and the elimination of many first and second-order streams considered to be insignificant or a nuisance by developers.

These physical transformations alter the natural storage and drainage capabilities of a watershed. In pristine watersheds, the naturally uneven and vegetated landscape traps and stores water during rainfall events and slows down the overland movement of stormwater runoff. In such watersheds, a portion of the stormwater runoff slowly infiltrates into the ground, and vegetation aids in the evapotranspiration of water to the atmosphere. First-order[7] channels, which are typically ephemeral, play an important role in keeping both sediment and runoff distributed among many small channels (Dunne and Leopold 1978). Furthermore, these small tributaries play an important role in delaying the movement of flood peaks, providing channel storage, and slowing the average speed of water delivery to the larger stream channel. This naturally efficient hydrologic regime is significantly changed as the watershed becomes increasingly impervious to infiltration.

Impervious surfaces are the major contributor to the change in stream hydrology (Scheuler 1995b, Horner and May 1998). As watersheds become urbanized, impervious surfaces such as roads, rooftops, and parking lots replace forests, soils, rills, swales, and first and second-order tributaries. Consequently, rainfall flows rapidly overland, less water infiltrates into the soil, and evapotranspiration is reduced. Depending on the extent of impervious cover in the watershed, the annual volume of stormwater runoff can increase by up to 16 times that for natural areas (Schueler 1995a).

[7] Channel segments are assigned order numbers to describe the stream channel network. A first-order channel has no tributaries. Where two first-order channels combine, the channel segment becomes second-order. Further downstream, segments of channels are assigned higher order numbers as the drainage system unites into a final single channel at the bottom of the basin.

This decreased infiltration and reduced storage capacity of the watershed causes a reduction in soil and groundwater recharge and more of the stream's annual flow is delivered as surface storm runoff rather than baseflow. This ultimately leads to reduced base flows in the stream during the late summer when precipitation is at its yearly low (Leopold 1968, Simmons and Reynolds 1982, Rood and Hamilton 1994). In smaller headwater streams, the reduction in base flow can cause a perennial stream to become seasonally dry. In larger urban streams, the reduced base flow can significantly decrease the wetted perimeter of the stream that is available for aquatic habitat (Scheuler 1992).

More dramatic changes to the stream are visible as a result of increased stormwater runoff on the watershed. An increased volume of stormwater runoff, combined with a faster delivery of water to the stream (decreased time of concentration) creates increased peak discharges at the outlet of the developed area (Dunne and Leopold 1978). The combination of greater discharge, rapid time of concentration, and smoother hydraulic surfaces can create highly erosive water velocities that can also be detrimental to fish migration. In addition, watershed development increases the frequency of bankfull flooding events (Bedient and Huber 1992). Therefore, urban streamflow becomes flashy and the greater number of bankfull floods subject the stream channel to continual disturbance by channel scour and erosion.

3.2.2 Changes in Stream Morphology

Streams must respond and adjust to the altered hydrologic regime that accompanies urbanization. The primary adjustment to the increased peak flows and higher runoff volumes is an increased channel cross-section (Hammer 1972, Booth 1990). This is often achieved by bank erosion and accelerated lowering of the streambed (downcutting). This rapid erosion results in an increased sediment load and causes channel instability. As the gradient of the stream adjusts to accommodate the frequent floods and increased sediment load, the series of pools and riffles characteristic of alluvial streams is eliminated or degraded. The loss of pool and riffle structure in streams greatly reduces the availability and diversity of habitat for the aquatic community (Hynes 1970, Newbury and Gaboury 1993).

Over time, the sediment size distribution of a stream is also modified by urbanization. Typically, the grain size shifts from coarse-grained particles toward a mixture of fine and coarse-grained particles (Schueler 1992). Coarse gravels and cobbles become embedded with sand, silt and clay which reduces the circulation of water, organic matter and oxygen to the filter-feeding aquatic insects that live among and under the bed sediments (Horner and May 1998). These insects are the basic foundation of the stream food chain. In addition, embedding of the stream sharply limits the quality and availability of spawning areas for trout and salmonids.

Increased bank erosion and sedimentation also results from the removal of riparian vegetation. In many alluvial streams the loss of bank stability from riparian vegetation will cause the stream channel to move laterally. Furthermore, woody debris that is recruited over time from the riparian forest is associated with pool formation and provides instream cover for fish (Lienkaemper and Swanson 1987).

Once a floodplain becomes cleared and developed, it loses its ability to store sediment and accommodate flood flows. Flooding becomes more frequent and inevitably becomes a nuisance to the people living there. In the past, municipal engineers solved this problem by channeling streams to increase their ability to carry water away as quickly as possible. Shallow and wide natural streams are reshaped to form deeper and narrower trapezoidal channels, which often lead to channel entrenchment and bank failures (Newbury and Gaboury 1998). Often, these unstable streams are channelized and become converted to elaborate storm drains confined to arrow-straight concrete channels (Leccese 1996). To make matters worse, an underground network of storm drainpipes typically replaces small headwater streams. With few natural mechanisms left to dampen stormwater runoff, these confined channels contain water with detrimentally high velocities and there is little hydraulic habitat suitable for aquatic organisms within these "flumes".

Other inevitable consequences of urbanization are stream crossings by roads and pipelines. Often streams are relocated or straightened and heavily armoured to accommodate these structures. Culverts and weirs have been designed without regard to fish populations and often create barriers to the migration of both resident and anadromous fish (Furniss et al. 1991).

3.2.3 Changes in Water Quality

Stormwater runoff collected from impervious surfaces is a significant source of pollutants in urban streams. During storms, organic matter, heavy metals, oils, gasoline, pesticides, bacteria, excess nutrients and sediment are washed into sewers, or directly into urban streams. In older cities, combined sewer systems carry both domestic wastewater and stormwater runoff. When stormwater flows are large, these combined sewer systems are usually designed to overflow into the natural streams at a number of locations. These combined sewer overflows have been recognized as a significant source of pollution and can seriously degrade the quality of receiving waters (Lampe et al. 1996).

Overland flow from urban areas also causes movement of fine sediments into channels throughout the year; when coupled with land-cover changes, the sediment load can increase by many orders of magnitude and the predominant grain size distribution can shift to much finer fractions (Booth 1998, Horner and May 1998).

Water temperature is also an important measure of water quality and Galli (1990) has linked an increase in stream water temperatures to the imperviousness of the contributing watershed. Impervious areas have local air and ground temperatures that are 10 to 12 degrees Celsius warmer than the fields and forests they replace (Galli 1990) and a lack of riparian cover and ponds further amplify stream warming (Karr and Schlosser 1977). The thermal loading severely disrupts aquatic organisms that have finely tuned temperature limits (Bjornn and Reiser 1991). Cold-water organisms such as trout and stoneflies are particularly sensitive and often become locally extinct in intensively developed streams (Steedman 1988).

3.2.4 Changes in Stream Biodiversity

The ecology of urban streams is transformed by the shifts in hydrology, morphology and water quality that accompany the development process. Booth (1991) demonstrated that a sharp threshold in habitat quality exists at approximately 10 to 15% imperviousness in urban watersheds. The diversity, richness and composition of the benthic community in streams drop sharply with urbanization (Klein 1979, Pedersen and Perkins 1986, Steedman 1988). The number of fish species also decreases with urbanization, particularly salmonid fish species, who have a strong dependence on the substrate for feeding and spawning (Klein 1979, Luchetti and Fuersteburg 1993, Horner and May 1998).

A stream ecosystem goes beyond the boundaries of its flowing water. Riparian forests, floodplains, wetlands, seeps and springs, and ephemeral channels contribute ecological functions and processes upon which the stream community depends. Many plant and animal communities have adapted to the natural flow regime of the river and therefore, isolating the floodplain from overbank flows will affect productivity and diversity (Poff et al. 1997). Naiman et al. (1993) describe in detail the role of riparian corridors in maintaining regional biodiversity.

3.2.5 Effects of Urbanization on the General Attributes of River Ecosystems

It is helpful to re-visit the general attributes of alluvial river ecosystems to illustrate the challenges associated with urban river restoration (Table 3).

Table 3: The effects of urbanization on the general attributes of alluvial river ecosystems.

General Attribute of Alluvial River	**Changes due to Urbanization**
Spatially complex channel morphology	• loss of structurally complex physical environments • loss of headwater streams, small tributaries, and estuaries • decreased diversity, richness and composition of aquatic and riparian species
Predictably variable instream flows and water quality	• altered hydrology • degraded water quality
Frequently mobilized channelbed surface	• bankfull discharge increased and more frequent
Periodic scour and fill of the stream bed	• trend toward downcutting • loss of pool and riffle sequences
Balanced fine and coarse sediment budgets	• increase in fine sediment input • decrease in coarse sediment as stream is channelized
Periodic channel migration	• urban infrastructure or land use typically restricts natural meander wavelengths
A functional floodplain	• floodplain is developed and isolated from the stream
Infrequent channel resetting floods	• flooding is highly controlled

Self-sustaining diverse riparian plant communities	• isolation of floodplain and altered hydrology • removal of streamside vegetation • invasion of exotic species
Naturally fluctuating groundwater table	• sewer systems • loss of wetlands • increased imperviousness • decreased infiltration

For urban stream restoration to be self-sustaining, an emphasis must be put on the critical processes by which watershed urbanization affects physical and biological stream-channel functions. Attention is generally given to observed channel changes, as the stream channel itself is almost always the focus of attention for restoration efforts (Claytor 1995, Schueler 1992, Booth 1998). However, it is important to recognize the links between the upland watershed and the stream ecosystem. Understanding how urbanization degrades a river system is critical in guiding choices for realistic rehabilitation goals or strategies.

3.3 Key Tools of Urban Stream Restoration Design

The physical limitations that urban watersheds place on stream restoration projects are profound. The goal of restoring urban stream habitats to pristine conditions, as outlined in Table 2, is a utopian view; conditions that existed prior to urbanization cannot be restored in this same area without removing the city altogether. The natural pattern of channel altering disturbance and recovery that is fundamental to the health of many wild river systems is rarely possible in the urban context.

However, with modified expectations, we can maintain and improve habitat conditions within city streams. Stream restoration projects can be designed to compensate for stream functions and processes that have been diminished or degraded by urbanization. Even in the worst cases, where streams have little room to meander, erode, deposit, and adjust their slopes, stream restoration projects can be designed in a way that maximizes the environmental values of the resource. Urban stream restoration often involves the same principles that one would use to restore a stream in a more natural environment. Schueler (1996) recommends seven restoration tools that can be applied to urban streams to help restore a new equilibrium and improve stream biodiversity. The best results are obtained when the tools are applied together (Schueler 1996).

Tool 1. Partially restore the predevelopment hydrological regime. The primary objective is to reduce the frequency of bankfull flows in the contributing watershed. This is often done by constructing ponds or wetlands that capture and detain stormwater runoff, or by increasing infiltration throughout the watershed.

Tool 2. Reduce urban pollutant pulses. To improve water quality, it is important to reduce concentrations of nutrients, bacteria and toxics in the stream, as well as trapping excess sediment loads. Generally, pollutant inputs can be reduced using filtration methods (wetlands, riparian buffers, pipe retrofits), watershed pollution prevention programs, and the elimination of combined sewer outfalls into the stream.

Tool 3. Stabilize channel morphology. If possible, it is important to restore equilibrium channel geometry. Channel width, depth and grade can be adjusted to provide just the velocity required for the transportation of the sediment load supplied from the drainage basin. This may involve grade control techniques (e.g. riffle or weir construction), bank stabilization techniques or the re-alignment of meanders.

Tool 4. Restore instream habitat structure. In urban streams, erosive floods, sedimentation, or channel straightening often degrades instream habitat features such as pools and riffles. Regular flood flows may re-build the features, but in many cases, the lack of suitable bed materials and changes in the flow regime can eliminate suitable invertebrate and fish habitats for decades (Newbury et al. 1996). Key restoration tools include the creation of pools and riffles, wing deflectors, and boulder clusters to create locally varied flow.

Tool 5. Re-establish riparian cover. Riparian cover helps to stabilize stream banks, provides large woody debris and detritus to the stream, and helps reduce water temperatures. Riparian vegetation also acts as a natural filter to reduce the input of sediment and debris carried by surface runoff and increases infiltration of overland flow into the soil. Re-establishing a riparian plant community along the stream may entail active reforestation of native species, removal of exotic species, or changes in stream temperature.

Tool 6. Protect critical stream substrates. A stable, well-sorted streambed is often a critical requirement for fish spawning and secondary production by aquatic insects. This involves giving priority to minimizing fine sediment delivery to the stream. Where fine sediment or algae has settled, stream substrates can be cleaned by the construction of flow concentrators such as v-notched riffles or wing deflectors. Providing shade to the stream may help to control prolific algae growth.

Tool 7. Allow for recolonization of the stream community. It may be difficult to re-establish the fish community in an urban stream if fish barriers prevent natural recolonization. Fish barriers such as culverts, weirs and dams can either be removed, or re-designed to allow fish passage.

Although these restoration tools may seem simplistic, they apply ecological and geomorphic principles to constrained urban stream settings. Many restoration guidebooks or frameworks emphasize restoring systems to a natural state. The China Creek case study clearly demonstrates that, in urban cases, this is not achievable. Physical changes to the land surface – as well as social, economic and institutional systems within the watershed – influence how restoration should be approached. Integrating all these variables into a framework is a challenging task as expertise is required from many disciplines.

3.4 Common Elements of Successful Projects

The physical and social settings vary widely among stream restoration projects, yet lessons can be gleaned from experience and observations of many restoration projects. Based on my literature review, I identified seven elements common to successful urban stream restoration projects. These elements are:

1. An Understanding of Geomorphic and Ecological Processes

Restoration goals and objectives be must sensibly formulated and evaluated only in the context of geomorphic and ecological processes. While social and institutional factors are clearly important, they do not guarantee that the physical modifications undertaken are necessarily beneficial to the physical and biological processes in the stream.

Using a "cookbook" approach to restoration design does not address the underlying causes of the degraded river condition. Imitation of channel forms believed to be suitable or prescribed by adherence to a classification scheme are rarely successful (Frissel and Nawa 1992, Kondolf 1996).

If projects are designed without an understanding of geomorphic and ecological process unique to the study stream, the restoration project will be ineffective at best. At its worst, it may produce additional degradation of the very resource it was intended to repair.

2. *A Watershed Perspective*

Successful restoration requires a thorough knowledge of the observed problem and how this problem interacts with other processes in the watershed. Restoration strategies must go beyond treating a localized problem, such as bank erosion, and identify the combination of factors causing the problem. Repairing excessive erosion through bank stabilization projects may be totally ineffective if the source of the problem remains untreated. Stream conditions are a consequence of the overall health of the watershed, and habitats should not be managed in isolation.

A watershed perspective recognizes that people are an integral part of the urban watershed. Social systems and institutional systems have played a significant role in watershed and stream degradation and, therefore, they are an important part of the solution. Cairns (1997) introduces the term eco-societal restoration, defining it as ecological restoration with the human component of the ecosystem actively participating in the process. Cairns (1997) points out this usually requires a willingness to alter social behaviours and develop new relationships between society and natural systems. Therefore, it makes sense that successful restoration projects often have both ecological objectives and social objectives (Riley, 1998). A social objective can include a restoration of community.

CASE STUDY 1: Bellevue Washington, USA[8]

Bellevue is a suburban community with a population of 102,000. Citizens recognized that the rapid urbanization of their community was stressing the area's remnant streams. As a consequence, a small group of citizens formed the Citizen's Advisory Committee on Stream Resources. Water quality of local streams was deteriorating and increasingly high instream flows were causing erosion and channel widening. A study by the University of Washington predicted the destruction of the Kelsey Creek fishery unless action was taken to prevent further degradation.

In 1972 the City adopted an open streams philosophy and established a regulatory framework to preserve open streams and their associated corridors. Rather than building conventional networks of underground sewers to remove stormwater runoff, the City decided to augment natural drainage systems to handle urban stormwater. By the 1980s, Bellevue had what was considered a groundbreaking storm drainage system, which maximized the use of natural watercourses and their riparian zones. Stream corridors and wetlands were acquired and restored, and flood control sites were constructed. The system is characterized by a fine structure of naturalized local waterways; ponds and wetlands periodically interrupt vegetated swales, creeks and streams.

This open drainage solution to stormwater management in Bellevue has not only reduced damages to local streams, it has aided in restoring environmental and community values. Working together, stormwater engineers and parks planners have woven a complex web of public open space that integrates the utilitarian public corridors of the city with older patches of parkland. Lake Hills Greenbelt Park best exemplifies the multi-use aspect of many of Bellevue's public open spaces. Contained within the park is Larsen Lake, a small body of open water surrounded by wetlands. The southern shore of the lake has a large organic blueberry farm and additional annual crops are planted on lands extending to the south. On paths through the wetlands and along the lake, steady streams of joggers and pedestrians have the opportunity to see waterfowl, hawks, songbirds and herons. Between the greenbelt and the residential area is an urban ranger station devoted to environmental education and adjacent to that is the city's demonstration organic garden. Together, these facilities form a

[8] Sources: City of Bellevue (2000), Girling and Helphand (1997)

hub of environmental education for the community. Residents have learned to appreciate a community landscape that seamlessly integrates natural systems.

In recent years, citizens have initiated programs to improve water quality in Bellevue. The Business Partners for Clean Water organization informs businesses about water quality issues and elicits their cooperation. City staff and volunteers provide workshops aimed at instituting clean-water programs and once businesses have developed a plan, they are signed on as partners. Another effort, the Stream Team, is aimed at educating the general public and involving them in awareness programs, such as street stencilling and stream restoration projects.

3. *Clear, Well-developed Goals and Objectives*

One of the critical steps in any restoration project is to decide on the overall goal(s) and objective(s) of the project. Goals can be abstract statements that reflect the views, perceptions and aspirations of the community. What is the desired future condition of the stream and its watershed? Objectives define more specifically what one hopes to achieve. Objectives should be specific, quantifiable expressions of one's goals. Indicators may be selected as a means of measuring the attainment of objectives.

Developing objectives facilitates understanding by participants as they can verbalize their individual perspective of the watershed, its problems and possible solutions (Turner, 1999). Objectives must be realistic and achievable. The established objectives will direct the entire restoration effort, so they must be developed with sound scientific input. A clearly stated goal helps keep efforts focused throughout the duration of the restoration effort. Clearly written objectives that can be quantitatively measured are critical for project evaluation and adaptive monitoring.

CASE STUDY 2: The Anacostia Watershed, Maryland USA[9]

The Anacostia watershed is a largely degraded urban ecosystem located in suburban Maryland that extends into two physiographic provinces and three political jurisdictions. The watershed is 440 km^2 and home to 805,000 people.

[9] Sources: Warner (1996), Shepp and Cummins (1997)

The history of ecological degradation is similar to most urban watersheds: the loss of important forest and wetland habitats, alterations to the natural drainage patterns and streamflow, increases in nonpoint source pollution, and discharges of combined sewer overflow and industrial waste into the river.

The Anacostia Watershed Restoration Committee (AWRC) formed and later created the Anacostia Watershed Citizens Advisory Committee to provide a formal avenue for citizen input and information. The AWRC identified and implemented restoration projects throughout the watershed, and eventually the members recognized the need to establish a framework to guide a more lasting restoration effort. The vision was for a comprehensive ecologically based restoration of the watershed.

The group identified six goals that addressed the primary problem areas in the watershed, and signed a Six-Point Action Plan. For each goal, the group identified 2-4 objectives that would help them achieve the goal.

Goal 1: Reduce pollutant loads delivered to the tidal estuary to improve water quality conditions by the turn of the century.

Goal 2: Protect and restore the ecological integrity of urban Anacostia streams to enhance aquatic diversity and provide for a quality urban fishery.

Goal 3: Restore the spawning range of anadromous fish to historical limits.

Goal 4: Increase the natural filtering capacity of the watershed by sharply increasing the acreage and quality of tidal and nontidal wetlands.

Goal 5: Expand forest cover throughout the watershed and create a contiguous corridor of forest along the margins of its streams and rivers.

Goal 6: Make the public aware of its key role in the cleanup of the river, and increase volunteer participation in watershed restoration activities.

Although the goals were an important step for guiding restoration efforts, the AWRC soon realized that the goals of the Six-Point Action Plan were broad and needed to be refined in order to make them:

- *specific* to individual subwatersheds and the tidal river;
- *achievable*, given a realistic assessment of the limits of environmental restoration technology and existing conditions;

- *measurable*, using effective water quality, and physical and biological indicators of improvement;
- *understandable* in terms that the public can readily and intuitively assimilate;
- *flexible* so that they can be adjusted in response to new developments in technology, watershed research, or funding.

In response to these requests, the AWRC assembled a technical oversight subcommittee to develop a system of indicators to track restoration progress. The system of indicators for the Anacostia watershed is being developed within the context of the Six-Point Action Plan, in that each of the indicators can be placed under one of the six goals. The indicators will not only act as a means for monitoring the watershed, they will also be used for education and outreach efforts, typically to the general public and elected officials.

4. Early Stakeholder and Public Involvement

To be effective, projects must have the support and cooperation of key stakeholders and those who are living in the watershed. Stakeholders are defined as any agency, organization, or individual that is interested in or affected by the decisions made by the restoration committee. A group of stakeholders might include interested citizens, developers, environmentalists, First Nations, consultants, planners and property owners. In addition, many local government agencies (e.g. parks, public works, transportation and planning agencies) may have a strong interest, and provincial or even federal resource agencies may wish to be represented. The definition of the public can be quite varied (Brenneis and M'Gonigle 1991). However, for stream restoration projects the public typically consists of local residents who live in the watershed.

Public and stakeholder participation is a means to making better decisions. Involving citizens can help to reveal issues of concern, provide an early warning system for potential problems, tap local knowledge and expertise, identify ways to explore a range of alternatives, and explore consequences of various choices (Shindler and Cheek 1999). Effective public participation requires broad access to all relevant information (Brenneis and M'Gonigle 1991). It therefore becomes an educational process through which participants become better informed.

When planning is conducted at the local level, people feel a sense of ownership in the plan because it is a compilation of their ideas and will fit their needs (Turner 1999, Saunders 1996, Schueler 1996). Also, when local residents are involved in the planning and decision-making they take on a role of responsibility, and the river or stream is less likely to be disrespected (Leccese 1996; Booth 1998; Lampe et al. 1996). People tend to have strong concern for and commitment to anything in which they invest time and effort (Brenneis and M'Gonigle 1991, Schueler 1996, Botelho 1998).

Citizen participation is considered by many planners to be a costly and time-consuming nuisance; however, the exclusion of certain community interests can undermine the legitimacy of the process or even halt the restoration initiative (Riley 1994 &1998). A high level of citizen participation can attract financial contributors to projects. It can also stimulate political support and interest in a project, and in turn attract money from government programs (Riley 1994).

Ideally, the public and stakeholders should be involved at the early stages of project planning and design to identify a broad range of issues and fully incorporate ideas and to avoid disgruntled feelings of not having been adequately consulted (Schaffer and Maelzer 1997, Morrison 1988, Shindler and Cheek 1999). Involvement is not only necessary during project planning and design stages; it is critical for the long-term success of any restoration project. When all the construction work is completed, it is the local community that has a vested interest in maintaining the health of the stream and monitoring the project for changes.

5. *Political Support*

An urban restoration project that affects numerous stakeholders will rarely be achieved without political support (Riley 1998). Gaining political support is much easier if the public supports restoration ideas and plans. It is advantageous to put local representatives in a situation where they will gain in public image if they support the restoration plans. Sometimes political support consists of the personal commitment of a politically influential person for a project. Other times, building political support may mean developing a rapport with city council or with agency representatives.

Involving local politicians and their staff is beneficial. Local representatives have great influence over whether a project will receive financial assistance. A grassroots approach to watershed restoration, where actions start within local communities, will inspire or help prompt governments and institutions to action (McGurrin and Forsgren 1997).

6. Effective Communication and Education

The importance of communication cannot be overstated. Even the most technically sound and ecologically significant restoration projects are unlikely to succeed if people do not understand and support them (McGurrin and Forsgren 1997, Schaffer and Maelzer 1997). Whether on private or public lands, the need for education and communication throughout all stages of a restoration project is important. To achieve effective communication, information must travel in both directions; restoration professionals should always be soliciting input from other participants (Turner 1999).

To develop public and political support for restoration projects, professionals must be able to communicate the consequences of land management, causes of degradation, and the many social and economic benefits that accrue from healthy watersheds. Watershed issues and concepts are unfamiliar to many watershed stakeholders. In large cities, it can be a challenge to reach out to minority language groups within the watershed; however, strategies exist (Dobson 1995), although they often require a higher budget.

If the restoration project involves substantial change within a community, a strong educational program that involves local residents early in the restoration process can help explain the purpose of projects and provide support for the most intrusive changes (Claytor 1995). Education is more likely to occur in the context of a personal relationship than through anonymous information provision (Shindler and Cheek 1999). In other words, people tend to respond to stories, analogies, or examples better than through receiving brochures or reports. Effective and personal communication will also help affected publics discover the opportunities to take an active role in the restoration process.

CASE STUDY 3: Restoring the Waters Project, Fairfield Australia[10]

The Georges River Watershed in southern Sydney is a fast growing urban area (920 km^2) with nearly 1 million residents. Large-scale development and deforestation led to

[10] Source: Schaffer and Maelzer (1997)

increasingly severe floods and, as a result of those floods, extensive mitigation was taken. In the Prospect Creek subwatershed, Clear Paddock Creek was channelized and lined with concrete. The surrounding subdivision was sewered and stormwater outlets discharged into the channel. During significant rainfall, the velocities in the channel are extremely high, which counteracts any instream habitat requirements. The area adjacent to the channel is open grassed parkland with some remnant and planted trees.

The Australian Conservation Foundation (ACF) would like to see Sydney's canals and creeks become an interconnected system of river habitats allowing the movement of animals and people through the urban landscape. The ACF formed a project steering committee and selected Clear Paddock Creek as a demonstration site to illustrate the benefits of creating a more biologically diverse urban waterway. Their plan is to deconstruct the existing concrete stormwater channel and reinstate a more natural watercourse.

Once the optimum site for restoration was selected, the committee developed a formal strategy for community consultation and involvement. Strategies for reaching the community included: three public meetings, a field trip and open house, a survey, media coverage and a project brochure. As well, informal consultation began with city council, local schools, and several community groups in the area.

The Fairfield Council demonstrated serious interest in the project and the Directors of all the Council's departments attended the first presentation of the project in September 1994. The project was given 'in principle' support by the Council's Priority and Directions Committee and it established a multidisciplinary team to analyse and prepare a constraints plan for the project. On February 21, 1995 the project was presented directly to the Council's Priority and Directions Committee, which endorsed the project, nine votes to two.

However, just one day later, the first public meeting was held and despite support given from the state and local government and community groups, there was mixed response from local residents. The project steering committee gave several reasons for the response. First, many residents had not received the brochure or flyer for the meeting and had no knowledge of the background issues or details of the project. Secondly, there were residents who believed the concrete channel provided a guarantee against flooding and they had concerns about the safety of their property. Thirdly, the initial concept plans displayed at the meeting were perceived as final plans, and the residents believed the project was a fait accompli and would go ahead, regardless of their input.

Due to the need for continued community consultation, Council decided to defer the decision to support the Restoring the Waters Project until the final results of the community consultation project were available. Fortunately, Council offered to provide funding for the consultation process, as there was no money in the Restoring the Waters budget for this type of expenditure.

Community support was successfully turned around after a second public meeting and a field trip. A workshop session in the second meeting provided much more education on the issues, and residents were given the opportunity to voice and discuss their concerns. Also, the Community Open Day and Wetlands Field Trip provided a great deal of information on the problem of stormwater and potential management solutions. A survey at the end of the Open Day showed a majority supported the project. However, the extended community consultation process resulted in running over schedule by one month.

The support from Council was not so easily won; councillors voted 6 to 5 against the Restoring the Waters Project. The Steering Committee and community representatives lobbied hard for the project and, finally, the Council unanimously supported the project. The public support gained for the project was critical to achieve the support of the City Council.

7. *Project Monitoring and Evaluation*

Monitoring and evaluation are crucial for an adaptive management approach to restoration. Adaptive management is a useful approach for habitat restoration because it offers a mechanism for modifying techniques and improving original plans as projects evolve. It also allows managers to experiment and select among several options when they are unsure which actions will bring the desired results. Most important, post-project performance evaluation allows us to avoid repeating mistakes and to develop an understanding of how rivers respond to restoration actions.

Monitoring efforts should determine whether (1) the restoration plan has been designed and implemented properly, (2) the expected results are being achieved, and (3) what modifications to the plan, if any, are needed in future efforts. By comparing this information to pre-project assessments, one can characterize changes in conditions, document successes, and garner support for additional restoration work (Wood et al. 1997).

Monitoring also provides a valuable opportunity for agency scientists to enlist the support of local citizens in gathering ecological data. With guidance from agencies, citizens can build valuable long-term data sets and become more knowledgeable about how natural and artificial disturbances affect the integrity of the watershed in which they live.

4.0 An Integrated Framework

Each stream restoration project has unique physical, ecological, social, and economic conditions that dictate activities to meet specific needs and changing circumstances. Therefore, this integrated framework will have to be adapted to each unique project. Obviously, the amount of planning required for a project depends largely on the scope of the project.

The planning framework that follows has 5 stages that are common to most stream restoration projects: (1) Feasibility, (2) Planning, (3) Design, (4) Implementation, and (5) Monitoring. All of the stages are interdependent, and iterative in nature (Figure 2). Many of the fundamental tasks may need to be repeated or may occur simultaneously with other tasks. Following the general framework will prevent disjointed decision-making and facilitate the organization of successful stream restoration projects.

4.1 Feasibility of Restoration

Before spending copious amounts of time and money on detailed stream restoration designs and plans, it is useful to assess the feasibility of restoration within a constrained urban setting. Is it a realistic goal to attempt to restore a stream? Restoration goals or strategies cannot be objectively set until the current health of the watershed and the stream is understood. There is no point trying to immediately restore a biological community within a stream if pollutant loads into the stream are not addressed first. Likewise, it may be futile to re-vegetate the stream banks if the stream is undergoing accelerated bank erosion in response to altered hydrology of a newly urbanized watershed. Therefore, the restoration process must begin with an analysis of existing stream channel and watershed conditions.

The feasibility stage is not the time to gather detailed stream reach data. The purpose of this stage is to take a cursory look at the watershed and stream conditions, gather information, and identify issues or problems. This stage will help to establish reasonable goals and objectives for restoration.

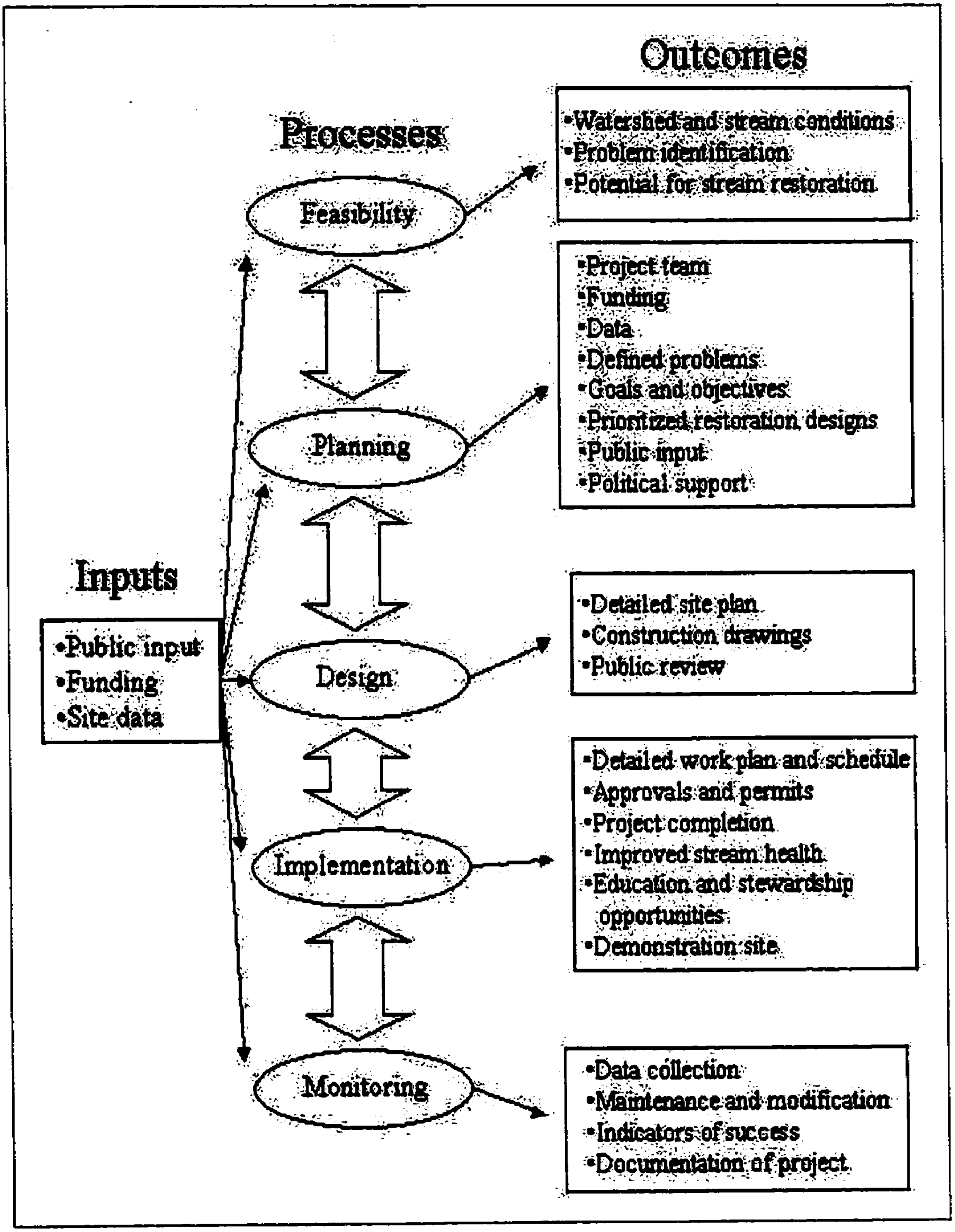

Figure 2: The inputs, processes and major outcomes of the planning framework.

4.1.1 Scale of Watershed

Claytor (1995) and Schueler (1996) suggest local urban watershed initiatives take place at a subwatershed scale. A subwatershed usually encompasses first or second order tributaries to the main stream and has a manageable drainage area (4 to 6 km^2) that will vary depending on the region. When the watershed of focus is too large, a bewildering number of issues and problems complicate the picture: costs for analysis and monitoring are extremely high, the number of stakeholders in the plan proliferates, political jurisdictions overlap, links between stream quality and land use patterns become difficult to isolate, identifying sources of water quality problems becomes bewildering and plans can take decades to implement (Schueler 1996).

Topographic maps or aerial photographs of the stream region are necessary to determine the watershed boundaries. In urban areas, it is typical that many first and second order tributaries have been relegated to pipes and therefore it is often necessary to obtain municipal drainage maps to determine drainage patterns and watershed boundaries.

4.1.2 Land Use and Development History

Land use and zoning maps provide valuable information about an urban watershed. Three major questions to answer are: (1) where are the open spaces (e.g. wetlands, parks, conservation areas) in relation to the stream? (2) what land is publicly owned and who owns major tracts of private land near the stream? (3) what stage of urbanization is the watershed in?

Open spaces are important places in watersheds as these areas can potentially be integrated into a stream restoration plan. For example, a nearby park may be a potential site for a stormwater detention pond to help attenuate flood flows in the stream to be restored. Likewise, it is important to know where the public land is located within the watershed. When large or significant parcels of land near the stream are privately owned, establishing who the landowners are is important, as they are by definition stakeholders, and should be included in the stream restoration process. Availability and ownership of land is especially important for projects that require land to daylight streams, construct storm water management ponds, reconstruct stream meanders or re-vegetate the riparian zone.

Determining the watershed's stage of urbanization is important for assessing the condition of the stream and for developing stream restoration strategies. If the watershed is in the beginning of a new urban development phase, then greatest efforts need to be put toward protecting the stream (e.g. protecting floodplains as greenways and setting any new development back from the stream). For this early development stage, restoration projects should focus on managing erosion, sediment yields and stormwater.

4.1.3 Impervious Cover

An estimate of impervious cover is a good indicator of the potential quality of an urban stream (Arnold and Gibbons 1996). Schueler (1995) outlines an urban stream classification model whereby an urban stream can fall into one of three categories based on the amount of impervious cover found in its subwatershed:

1. Sensitive: 1 - 10% impervious cover
2. Degrading: 11 - 25% impervious cover
3. Non-supporting: 26-100% impervious cover

Stream restoration goals and strategies must reflect what is actually attainable and classifying an urban stream may help determine realistic priorities for rehabilitation. For example, in a subwatershed that has 80% impervious cover, the priorities should be directed toward improving channel stability and water quality before spawning platforms are built for fish.

4.1.4 Prior Biological and Physical Information

A review of any past data (physical, chemical, biological) will help to identify problem areas and may be useful baseline data. Reports and data will most likely be dispersed among local consultants, municipal, provincial and federal government agencies. Research on riparian zones, instream habitat and water quality will determine where information already exists and where there are gaps. Discovering what information is available and reliable is important so that data is not collected twice.

Information need not be only quantitative; qualitative assessments by managers, landowners or fishermen who are familiar with the stream can also constitute a highly valuable source of information. The integration of local information sources offers an excellent opportunity for entering into contact with local representatives and users and involving them in the early stages of the planning process (Burton 1995).

4.1.5 Municipal Drainage Plans

A map of the existing municipal drainage network and the municipal drainage plans will help determine the drainage patterns within the watershed and provide some insight into stormwater management problems within the watershed. Important details to determine are whether the sewers in the area carry a combination of stormwater and sewage, or if there are separate pipes that carry stormwater only. If water quality is a potential issue in the stream, the storm drainage outfall pipes should be located.

Master Drainage Plans will disclose the city's goals with respect to stormwater management and may reveal opportunities to work together on projects. The impetus for much of the restoration work currently being practiced in urban watersheds is to improve stormwater management within the city (Task Force to Bring Back the Don 1991, Lampe et al. 1996, Girling and Helphand 1997, Helfield and Diamond 1997, Schagrin 1997, Riley 1998, Pederson 1999). Natural drainage systems on the land surface that handle urban stormwater can provide opportunities to create urban open space that meets the recreational needs of urban populations, while at the same time serving clearly defined environmental functions.

4.1.6 Current Social and Political Feasibility

Undertaking restoration projects within cities can be challenging and success often depends on public interest and political will. Both public interest and political will can be generated with time and energy; however, it is helpful to look for indicators that might impart optimism. Questions to be considered are:

- Are there currently any local initiatives to protect and restore the environment within the city?
- Have there been previous stream restoration projects in the city?
- Are there any successful stream restoration projects that have been documented and could be used as an example to sell your ideas?

- How active is the community within the watershed? Are there any existing environmental groups or neighbourhood associations that would be interested in stream restoration?
- Who are the key influential people in the community and do these people have any personal links to streams or fish habitat?
- Does stream stewardship relate to other community concerns such as water quality or urban green space?

A positive answer to any of these questions suggests that generating public and political interest in a local stream will likely be achievable. Negative responses to these questions do not imply that restoration is infeasible; however, it does suggest that the restoration planning stage will be critical to the success of the project. Public interest and political will take time to develop.

4.1.7 Problem Definition and Restoration Opportunities

The feasibility stage is important for developing a good understanding of the stream, the watershed and the community within the watershed. This understanding may be based on many different resources including: maps, existing biological or physical data, historical anecdotes, photographs, site visits to the stream and activism experience within the community.

The last task during the feasibility stage is to identify problems with the stream and determine if any of these problems could realistically be alleviated with stream restoration. Problems can be very general such as: sedimentation in sensitive instream habitat, reduced fish harvest, damage to riparian areas or eroding banks. Potential restoration opportunities will be apparent if watershed and stream problems are correctly identified. During the planning stage, when more people are involved, including experienced professionals, the problems will be assessed and clearly defined and restoration opportunities will be explored further in more detail.

Once problems are identified, a plan must be developed to convince others that time, energy and resources should be invested into stream restoration. Depending on the scope of the project, this can be a challenging task. A well thought out plan establishes a framework for addressing critical restoration issues, problems and needs.

4.2 Planning

Projects that occur through a logical process of plan development tend to be more successful (FISRWG 1998). A logical process may convey visions of a clearly defined step-by-step process. However, to be adaptive, the planning process should remain flexible and iterative. Lessard (1998) describes an adaptive approach to planning and decision-making where new information is identified, evaluated, and a determination is made whether to adjust strategy or goals.

The six steps I propose for the planning stage are somewhat sequential, yet also iterative (Figure 3). The planning process begins by building a project team; however, the team dynamics may change over the course of the planning process as new issues emerge and, therefore, this task runs in parallel with the others. The three core tasks of defining the problem, setting goals and objectives, and developing a restoration strategy are sequential, as each successive step relies on the findings or decisions made prior. The remaining tasks of securing funding and gaining public and political support are occurring throughout the planning process and throughout the remaining three stages (design, implementation and monitoring).

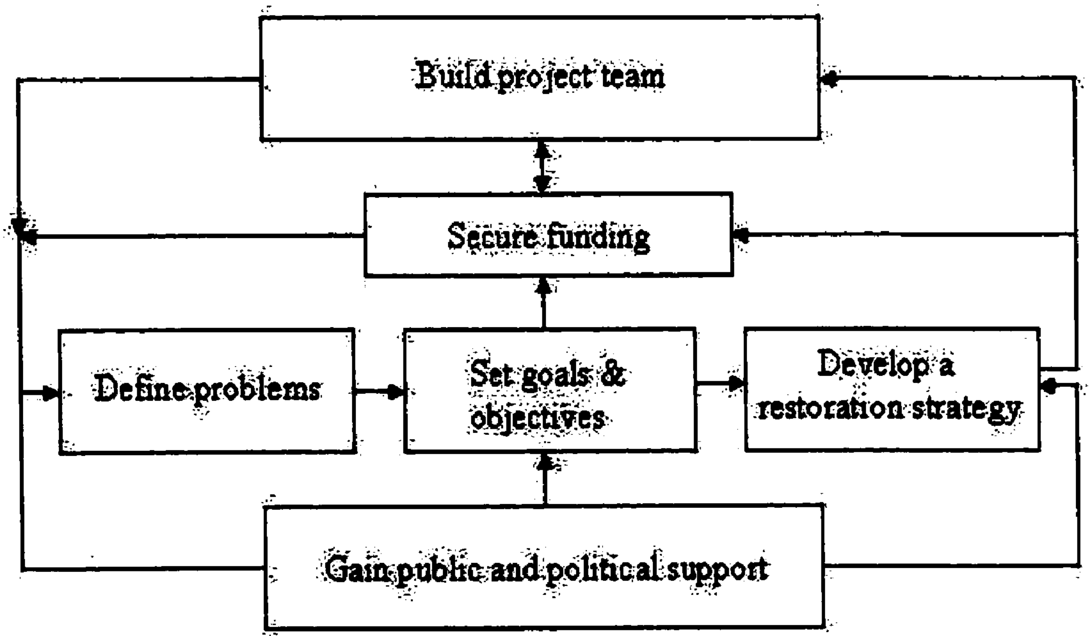

Figure 3: Six essential steps of the planning stage.

4.2.1 Building a Project Team

Coordination of the many elements of a restoration project in an urban setting needs ingenuity and determination, as well as skill. When developing a project team there are three important considerations to be addressed: who will be involved, who will lead the process, and how decisions will get made.

4.2.1.1 Who will be Involved

The complex ownership and myriad public and private interests within urban watersheds dictate that no single party or interest can by itself facilitate stream restoration at the watershed scale. It is critical to identify the key stakeholders in the watershed and to represent the diversity of the community. The exclusion of certain community interests can undermine the legitimacy of or even halt the restoration initiative. Anyone with a genuine interest in the goals of the group and anyone who will be affected by its work should be invited. Broad-based participation helps to ensure that self-interest or agency agendas do not drive the process from the top down (Riley 1998).

Interacting with some level of government will eventually be necessary, as any work within streams requires permits. It is advisable to establish a good working relationship with key government agencies in the watershed. This includes First Nations tribal councils or Indian Bands whose traditional territories are within the watershed boundaries. The benefits of involving government include being able to access specialized expertise, assistance in pushing through red tape, improved chances of receiving funding, legitimacy and influence with respect to other government agencies or elected governments (Community Stewardship 1995, Riley 1998).

Representation of stakeholders may be realized through partnerships. A partnership is an arrangement between two or more parties who have agreed to work cooperatively toward shared and/or compatible objectives and in which there is:

- shared authority and responsibility;
- joint investment of resources (time, work, funding, material, expertise, information);
- shared liability or risk-taking; and, ideally,
- mutual benefits (Community Stewardship 1995).

Establishing working partnerships among stakeholders is a good way for a group to broaden its expertise and access to resources. As well, partnerships provide a perfect platform for joint funding and cost-sharing; leverage is one of the most appealing aspects of a partnership arrangement (Tilt and Williams 1997).

4.2.1.2 Leadership

Good leadership often means the difference between success and frustration (Shindler and Cheek 1999). Regardless of the origins of the restoration initiative or the introduction of the proposed "solution," it is important that the focus of the leadership for the restoration planning process be at the local level – that it come from the people who are pushing for action, who own the land, who are affected, who might benefit, who are in a position to make decisions, or who can lead the community. Together, the stakeholders should decide which organization should take the lead role on the project.

The role of the lead organization is to administer the project, facilitate communication among all involved and interested parties, and lead the restoration initiative. The lead organization will serve as a central source that potential partners or volunteers can contact for more information. This organization should be skilled in leadership, scheduling, budgeting, technical issues, human relationships, communicating, and negotiating. Choosing an established lead organization is preferable so that there is sufficient stability to administer the project and to measure its long-term success.

Facilitation of a large group is challenging and it might be necessary for the leaders to form an Advisory Group or a Task Force to represent diverse interests within the watershed. Once again, it is critical to identify key participants who can commit themselves to a potentially lengthy project. The role of the advisory group is to advise the decision maker or the agency, organization, or individuals leading and initiating the restoration effort on the development of the restoration plan and execution of restoration activities (Federal Interagency Stream Restoration Working Group 1998). The advisory group will ensure that local values are taken into account during the restoration process, make diverse viewpoints and objectives known to the decision makers and identify the public's interest in the restoration effort.

Often, the advisory group will find it necessary to establish special technical teams, or subcommittees, to provide more information on a particular issue or subject. A strong technical base is critical as it allows for better understanding of the problems, sets the stage for making good decisions, and improves the credibility of the restoration plan (Turner 1999). Depending on the scope of the restoration initiative, several technical teams may be established to research topics such as: funding options, economic issues, public outreach, social and cultural issues, or stream structure and function. Members of the technical teams can also be members of the advisory committee or even the decision-making body.

Some Key Principles For Working Together
Source: Planning Ourselves In (1994)

- encourage an inclusive range of participants
- show respect for group members
- develop non-hierarchical organizational structures
- value everyone's time
- ensure all views are heard
- receive and give feedback
- share responsibilities
- choose do-able projects (simple ones that give everyone a sense of accomplishment)

4.2.1.3 Decision-Making Process

A group of individuals or organizations trying to solve important and complicated problems must agree on explicit, formal rules for decision-making (Bingham 1986, Cormick 1989). A decision rule is a mechanism to achieve closure on any particular decision. Common decision rules include: majority vote, unanimous agreement, having the person-in-charge decide *without* discussion, flipping a coin, delegation, and having the person-in-charge decide *after* discussion (Kaner et al. 1996).

Kaner et al. (1996) believe that group decision-making remains the best hope for solving difficult problems as it takes advantage of the full range of experience and skills of participants. They have worked with and led organizations for over twenty five years and their number one lesson is: if people don't participate in and "own" the solution to the problems or agree to the decision, implementation will be half-hearted at best, probably misunderstood and, more likely than not, fail.

Establishing one clear decision rule is not necessary. There are uses and implications for each rule and therefore, perhaps a time and place for each method (Kaner et al. 1996). What is most important is that all group members are aware of the decision rule being used when the group is working toward closure. If group decisions become difficult, participants should consider hiring a group facilitator to encourage the key values of full participation, mutual understanding, inclusive solutions and shared responsibility.

A well thought out and utilized decision making framework creates trust among participants and leaders, more commitment to the project, development of a respectful, supportive atmosphere, higher quality ideas, solutions that integrate everyone's goals, and an increased capacity for tackling difficult problems (Kaner et al. 1996).

4.2.2 Funding

Determining funding needs is very case specific and region specific. Funding for the various components of a stream restoration project will likely be found from a variety of sources. For long-term projects, different stages of the restoration process will likely be funded separately (e.g. planning and implementation).

Specific restoration activities can be matched to specific funding sources with related areas of interest. For example, if the stream restoration project is aimed at improving fish habitat within the stream, government funded programs that support habitat conservation should be researched (e.g. the Urban Salmon Habitat Program, Fisheries Renewal BC). If the stream restoration project includes community-based initiatives such as workshops, clean-ups or tree-planting, then local businesses (e.g. VanCity) who fund projects that improve the well-being of their local community should be pursued.

Funding will come easier as the project unfolds. If funding is secured from one source, it becomes easier to leverage funds from other sources. Also, funding is easier to attract when high profile activities are planned, and when government agencies are involved in the restoration process. When restoration projects are planned to coordinate with public works projects (e.g. reducing combined sewer overflows into a stream), a cost-sharing arrangement can usually be made.

As funding is a constant need at each stage of the restoration project, establishing a technical team to direct all funding acquisition is a good idea.

4.2.3 Defining the Problem

Once diverse and representative participants begin meeting, a more thorough understanding of the watershed's problems must be developed. A brainstorming session to identify issues or concerns within the watershed and the stream will certainly expand on the list of issues that was generated during the preliminary feasibility stage. Familiarity with the stream and its watershed will greatly enhance the list of issues. Site visits are always beneficial and, at this point in the process, the entire restoration committee should have visited the stream.

Issues can be categorized as institutional (laws, policies, rules and regulations), technical (standards, procedures, criteria), and public concerns or perceptions. The process of identifying issues serves to encourage the sharing of information and plans between government agencies, industry and the public. Most likely, everyone will learn from this exercise.

Recognizing the issues or challenges for stream restoration in the watershed is important for two reasons. Firstly, it will help to identify data gaps and research needs. Secondly, the list of concerns, issues or challenges will be important when setting goals and developing a restoration strategy.

Once existing data is reviewed, the restoration team must determine if further data is needed to properly assess the stream conditions. Collecting data can be expensive and time consuming, and will depend on the scope of the project, the risks involved and the available funds. Assessments should be issue driven and should provide a scientific characterization of the problems. For example, if the diversity of fish and benthic invertebrates in a stream has slowly decreased, water quality testing should be carried out to determine if any deleterious substances are present.

Lastly, to properly define the problem, all existing data must be analyzed. Links between stream condition and changes that have occurred within the watershed need to be established. After data has been collected and problems have been analyzed, the group should have an increased understanding of the current physical and ecological processes occurring in the stream and an understanding of community and social processes that are affecting stream conditions.

4.2.4 Developing Restoration Goals and Objectives

To develop goals, the restoration team must decide what the desired future condition of the stream is. Goals can be general statements that describe a vision such as 'improve the water quality of the stream.' For each goal, specific objectives must be defined that specify the exact characteristics of water quality to be achieved, such as 'increase dissolved oxygen by 20%.' In general, restoration objectives can be defined that specify (Pastorok et al. 1997: 94):

1. Target species, biological communities, or abiotic functions to be restored.
2. Site of habitat characteristics to be enhanced.
3. Spatial and temporal scale of restoration.
4. Performance criteria or indicators

Performance indicators are structural or functional elements of the ecosystem that are to be used to judge the success of the project (NRC 1992). The U.S. Environmental Protection Agency (1990) provides specific guidance on selection of ecological indicators that are applicable to stream restoration objectives.

Goals and objectives will be specific to each restoration project, yet the following guidelines are helpful when determining them:

- Goals should reflect the views and aspirations of the community and the stakeholders
- Objectives must be realistic and achievable
- Objectives should be quantitatively measurable
- Objectives should be developed with sound scientific input
- Restoration projects that achieve a number of objectives are easier to gain support for
- Goals can be incorporated from other municipal initiatives (e.g. greenways or public education)
- Goals and objectives form the basis for a monitoring program to evaluate the success of restoration projects

Thom and Wellman (1997) discuss in more detail the process of defining objectives for aquatic ecosystem restoration.

4.2.5 Developing A Restoration Strategy and Action Plan

Defining project objectives and developing a restoration strategy are important steps in the planning process because they ensure that a 'road map' for the project is in place. Deciding on the route may be a challenging task.

Very often many issues and problems are discovered with an urban stream and priorities must be established for restoration. Brainstorming solutions or strategies for achieving restoration objectives will provide the restoration team with a number of options for restoration. Given the typical constraints on streams in an urban setting, the restoration strategies should consider the seven tools of urban stream restoration design outlined in section 3.3. Subsequently, current stream restoration methods and techniques should be researched to determine which ones best meet the objectives.

It may be useful to create a decision framework to organize information and establish priorities for restoration proposals. Generating a list of criteria will help to establish priorities for restoration activities in the watershed. Some examples include:

- level of risk[11] to public safety
- potential benefits to the physical and ecological function of the stream
- potential benefits to the community
- costs
- likelihood of success; are the techniques well proven?
- compatibility with existing management goals and plans in the municipality
- compatibility with existing municipal, regional and provincial policies.

There will always be trade-offs between risks, benefits and costs. Together, all participants must decide on the relative importance of the established criteria. Taking on easy projects first will help a restoration team to develop viability and credibility within the watershed.

Developing a time line is an important part of developing a restoration strategy. Complicated daylighting projects such as the China Creek Project may have timelines on the order of decades. If goals are large and require years to accomplish, it is important to set

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[11] When evaluating risk, take into account the magnitude of adverse impacts and the likelihood of their occurrence.

interim goals to give the organization a sense of accomplishment and to maintain public and political interest.

Demonstration Projects
Source: modified from FISRWG (1998)

Consider phasing long-term projects and creating small demonstration sites. Demonstration projects help:

- develop trust and stronger communication among stakeholders
- focus on action; keep interest levels high
- give a sense of accomplishment
- demonstrate benefits
- enhance capacity at the local community level for working with various agencies
- provide a practical vision and provide a forum where technical issues and concerns can be discussed and advice given
- encourage innovative thinking
- contribute to the evolution of future projects
- gain public support and attract interested people
- raise public awareness
- establish credibility
- attract potential funders

After the three core tasks (define the problem(s), set goals and objectives, and develop a strategy) have been completed, the restoration team should have an increased understanding of biophysical and social needs within the watershed. As well, the team should have conceptual restoration designs for a number of sites, with each prioritized for action. A conceptual design is preliminary in nature and the amount of detail provided on drawings varies from project to project. Design drawings are site-specific and include principles and techniques and estimates of size and material requirements; however, they typically do not include construction specifications. A more detailed design is formulated during the design phase.

4.2.6 Gaining Public and Political Support

I discussed the benefits of including the interested public, stakeholders and politicians in the restoration process in section 3.5, and provided a case study to illustrate the importance of this process. Soliciting input and support from community interests is important at all stages of the restoration process, yet it is most critical during the planning process. During this planning stage, it is critical to inform people about the restoration initiative and communicate findings, plans and designs as they are developed.

The three critical means of achieving public and political support are: education, communication and public involvement. Tools for achieving these components are action-oriented, as this is critical for maintaining interest and participation in any restoration effort. These tools should be utilized as often as time and resources permit (see below).

Tools for Educating

- **Case studies** – illustrate similar projects in other cities
- **Field trips** – demonstrate important stream features and/or problems
- **School projects** – allow students to experience stream ecosystems
- **Training projects** – increase community capacity

Tools for Informing

- Public meetings
- Newsletters
- Press releases
- Web sites
- Brochures or fact sheets
- Radio and television announcements
- Telephone hotlines
- Report summaries
- Training seminars
- Community art
- Community mapping

Tools for Receiving Input

- Workshops
- Open Houses
- Task Forces
- Public Hearings
- Training seminars
- Surveys
- Interviews
- Focus groups
- Web sites
- Community mapping

Tools for Increasing Public Involvement

- Stream clean-ups
- Tree planting
- Invasive species removal
- Storm drain marking
- Public art projects
- Urban ecology adventures
- Community watershed festivals

4.3 Detailed Design

After the restoration committee has decided on a priority restoration strategy, restoration works must be designed and working drawings produced. The steps for designing a restoration project for a degraded urban stream do not differ significantly from the design steps required for a stream in a more pristine setting. Newbury and Gaboury (1994) and Riley (1998) give detailed design examples that illustrate the steps necessary to design instream restoration projects. The underlying design principle is to evaluate the present state of the stream and adjust the channel geometry and slope to a new form that can be maintained by the available streamflow (Newbury and Gaboury 1994). Where possible, stream reaches in the area (preferably with similar soils, gradient and drainage area) with functional habitat features can be used as design guidelines that allow instream habitat structures to be re-created naturally (Newbury and Gaboury 1994, Riley 1998).

Constraints on the design are site specific, yet will typically compromise the natural design. Likely design constraints include altered hydrology and space limitations due to urban infrastructure. Given the flashy nature of urban streams, the extreme flows are critical to predict for urban stream design. Peak flows may have to be attenuated by a wetland or detention pond. It will be equally important ensuring minimum flows in the stream and this may require flow augmentation or releases from stored water.

A detailed site survey of elevation changes (channel profile), channel cross-sections and distances from any permanent urban infrastructure will be necessary. A detailed site plan showing utility lines and permanent structures is important, as it helps prevent surprises in the field that can delay construction work and significantly increase anticipated costs. Once the restoration works have been overlain successfully onto the site plan, the design should be re-analysed for (1) flooding potential, (2) grade and sediment transport capability.

Flood control is an important safety issue and a dominant cause of complaints about urban streams (Malcom and Lancaster 1991). Designs must be tested for minimum and maximum flows and predicted water surface elevations should be plotted on the stream profile, and on a typical cross-section of the stream.

Adding instream structures or re-working of meanders results in changes to the channel grade. It is important the channel grade closely match the valley slope; otherwise, slope stability must be achieved by grade control structures (e.g. riffles, weirs, boulders) that dissipate energy and prevent downcutting and high erosional forces. Grade differences in weirs or culverts should be analysed to ensure that fish passage is not a problem. Lastly, stream power should always be estimated for selected flows to assess the ability of the channel to transport sediment and to avoid excessive erosion.

The final working drawings should include an estimate of quantities of all materials that are required for the restoration job and an estimate of machinery and labour requirements. All costs for the construction should be summarized.

Once the restoration works have been designed to meet the criteria outlined by the restoration team and the constraints of the site, the restoration team, the stakeholders and the public must review the plans. Communication of the plans is important and any relevant concerns or problems may have to be worked into a new design. There should be no surprises for anyone when construction begins.

4.4 Implementation

Implementation typically implies project construction. However, getting to the construction phase requires implementing many additional tasks to ensure instream construction is organized and approved. The most efficient way to ensure this is to draft a work plan and schedule that highlights a critical path to completing the construction.

The most important tasks to accomplish prior to construction are: (1) securing funding, (2) obtaining approvals and permits, (3) identifying a work window, (4) collecting baseline data, (5) sourcing materials, and (6) appointing contractors and work crews.

Identifying the tasks and their anticipated start-up and completion dates is essential. Often, a limited window of time exists when work within a stream is permitted. Assigning this responsibility to a single project manager will help to make certain the construction is properly timed. This person must be able to make quick and informed decisions and they will have final responsibility for ensuring the works are completed as per the construction drawings.

Once the final restoration drawings are completed, the restoration team will have a cost estimate for the construction of the project and funding should be secured for construction if it has not already been granted. If the planning stage for the project involved many stakeholders, and public and political support has been achieved, then securing funding should not be a difficult task.

Permit requirements vary from place to place, making early contact with permitting authorities vital in minimizing delays. In British Columbia, all work planned in streams with fish habitat must be approved by the Department of Fisheries and Oceans (DFO) and the Ministry of Environment, Lands and Parks (MoELP). Satisfying the requirements of the federal *Fisheries Act* and the provincial *Water Act* are one step in the approval process. Municipalities have bylaws under the *Municipal Act of British Columbia* that restrict work in and around watercourses. Urban instream work will most likely require approval by the municipal engineering department and possibly other municipal authorities. If representatives from these agencies have been involved in the entire stream restoration process, the necessary approval process will be identified early and approvals will be easier to secure.

Any work done within a stream should be coordinated and timed so that conflict with fish populations is minimized. The windows of allowable times when instream work can be tolerated (work window) are based on the fish species found within the stream to be restored. Timing windows should always be confirmed with DFO or MoELP personnel responsible for the local area in which the restoration will take place.

Before the stream to be restored is altered in any way, the restoration team must determine if there is sufficient baseline data for a monitoring program. Developing a monitoring plan *before* the restoration works begin is critical. Once the earth gets moved it will be too late to collect pre-restoration data, which is essential for an adaptive experiment.

A potentially rate-limiting task is sourcing the materials required. For example, if using native plants for the project, appropriate nurseries are not abundant and may only be available at certain times of the year. Waiting for materials needed during construction can delay the project, or even bring it to a stop if the time sensitive fish window closes.

Lastly, before construction begins a contractor and work crew must be hired. When installing instream structures it is advantageous to work with contractors who are familiar with instream work. Having an environmental monitor on-site will ensure that the ecological structure and function of the site are not destroyed. Volunteers from the community can be utilized for tasks that do not require a high level of skill. Organizing and recruiting volunteers takes time, but the rewards can be increased community commitment to the project and community empowerment.

Once construction begins, the project manager should be on site as much as possible. Existing site conditions are seldom as they appear on a set of engineering plans. Variability in landform and vegetation, surface water and ground water flow, and changing site conditions during the interval between the design and construction phases are inevitable. When such surprises do occur, a sound response must be based on the project manager's understanding of both the restoration goals and the principles behind the restoration design. For this reason it is advantageous to have the designer of the restoration works on the site to ensure the plans are carried out as per the objectives.

4.5 Monitoring

Restoration projects are not fully completed at the end of the construction process. Chance events such as physical or biological disturbances may modify restoration projects after construction. Uncertainties in design decisions cannot necessarily be overcome with either detailed site and context understanding or variable design approaches (Pastorok et al. 1997).

To deal with these realities, adaptive management provides a framework for learning from our actions. Adaptive management, as described by Holling (1978), formally requires that the site be considered a long-term experiment. This involves:

1. Monitoring of the site relative to the project objectives (including pre-project baseline or reference sites)
2. Analysis of the monitoring data to determine the effectiveness of specific restoration methods and techniques, and
3. Incorporation of 'experimental' results in further site manipulation and, as applicable, in other similar projects.

The main purpose of monitoring a restoration project is to determine the ecosystem response to a set of treatments. Monitoring is essential for effective management for the following reasons: to evaluate management effects on a given resource; to justify the expenditure of funds for restoring degraded resources; to optimize the allocation of funds among management alternatives; and to increase understanding of the systems being monitored (Kondolf and Micheli 1995).

The key purpose of monitoring with respect to adaptive management is two-fold. First, monitoring guides further selective manipulations of the project that improve the outcome relative to the stated project objectives. Second, monitoring allows evaluation of the effectiveness of specific restoration methods or techniques and determines if the objectives were achieved by the restoration activities.

Lessard (1998) proposes a less traditional monitoring protocol that monitors and evaluates social needs in relation to changing societal values and settings. Here, social values and needs are constantly assessed in relation to the validity of the desired future ecological condition. Societal values often change more rapidly than ecological conditions and may significantly deflect society's direction toward the desired future ecological condition (Lessard 1998).

The monitoring program must be developed to suit the needs of the project and the community. Available funds will play a large part in determining the scope of the monitoring program. Integrating volunteers and government agencies into the monitoring plan serves to reduce monitoring costs and encourages interest in the health of the stream.

5.0 Conclusions

The urban landscape is a combination of dynamic, overlapping social systems, ecological systems and management or institutional systems. Natural stream ecosystems are altered significantly by urbanization. Changes to stream hydrology, morphology, biology and water quality put constraints on stream restoration projects that make restoring natural stream processes difficult, if not impossible. However, some stream functions may be restored, depending on the social, economic and institutional constraints within the watershed. It is these constraints that typically dictate what restoration strategies are feasible in an urban watershed.

Guiding principles from the stream restoration literature and from the environmental planning literature form the basis of the framework developed to guide urban stream restoration (Table 4). *Both* ecological stream restoration principles and environmental planning principles are critical components of the planning framework I developed. The challenges of restoring urban streams are multidisciplinary and therefore, the restoration solutions must address all identified challenges.

The urban stream restoration case studies reviewed support the efficacy of these principles. The seven elements required to successfully complete an urban stream restoration project are: (1) an understanding of geomorphic and ecological processes, (2) a watershed perspective, (3) clear, well-developed goals and objectives, (4) early stakeholder and public involvement, (5) political support, (6) effective communication and education, and (7) project monitoring and evaluation. Developing political support for a project was not identified as a guiding principle from the literature review. However, after reviewing numerous case studies, it became evident that having political support is critical for projects that involve numerous stakeholders.

The seven elements required for a successful project can provide community groups, funding agencies and municipal governments with a useful checklist. The list can be used for evaluating prospective restoration projects, for guiding the selection of realistic restoration objectives, and for guiding tangible design and implementation of stream restoration projects to achieve their desired functions in an urban setting.

Table 4: Guiding principles for urban stream restoration projects.

Ecological Stream Restoration Principles	Environmental Planning Principles
Identify the cause of the problem, not the symptoms.	Problems are interdisciplinary – integrate knowledge from biophysical and socio-economic sciences
Set realistic goals based on the best available science.	Identify biophysical planning units – include people within the ecosystem
Maintain stream *function* (grade control, energy dissipation) when natural *processes* (i.e. migrating meanders) are not achievable.	Be goal-oriented – goals should reflect the views of the community
Be adaptive – there are always uncertainties	Emphasize a participatory process
	Utilize local knowledge
	Seek to meet local needs
	Develop local commitment to sustainability
	Recognize that systems are dynamic and uncertainties exist – adapt to and anticipate change

My methods for developing the planning framework were adapted to meet time constraints and maintain a reasonable project scope. However, I recommend that the information used to generate the list of seven required elements for a successful project be gathered using interviews in conjunction with the literature reviews. This way, a consistent definition for what participants consider to be 'successful' can be achieved.

The planning framework I developed can help to guide the process for restoring China Creek. Given the long list of physical, biological, social and institutional constraints associated with daylighting China Creek, it is evident that the project requires long-term commitment to develop a restoration design. The critical elements required to work towards a restoration design for China Creek are: (1) establishing a project team with experienced leadership, (2) developing public and political support for the restoration ideas, and (3) establishing a restoration strategy that implements components of the restoration design in phases.

The project team must represent all interests within the watershed, and leadership will be critical to the success of the project. I recommend the Vancouver Parks Board lead the process. They are well-established, government funded, and experienced at managing urban restoration projects within Vancouver. Leadership from the City will give the process legitimacy and facilitate the development of public and political support.

Gaining public and political support to daylight China Creek must involve educating and receiving input from all affected stakeholder s and public. Action-oriented events (i.e. field trips, community plays, site clean-ups, open houses) should be a priority to maintain interest and participation in the restoration effort. Politically influential people should be involved in the process.

Given the large scale of the China Creek restoration project, the time line to accomplish a daylighting plan could be in the order of decades. Therefore, it will be most important to establish small-scale demonstration projects that will serve as phases of the long-term plan to daylight the entire length of China Creek. An ideal first phase would be to daylight a small section of Gladstone Creek that flows into Trout Lake. This project would develop credibility of the restoration team, raise public awareness, attract additional funding for future phases, demonstrate the benefits of a daylighted stream, and contribute to the evolution of the design and implementation of future phases.

Restoring China Creek and other urban streams requires a well-developed plan that undergoes a logical planning process. The planning framework I developed will guide restoration teams through such a process.

Appendix 1 –Calculation of historical bankfull width of China Creek

When the China Creek drainage area is compared to empirical measurements from other streams in regions of similar hydrological settings (Newbury and Gaboury 1993), the estimated historic bankfull discharge of China Creek is approximately 2.5 m^3/s. For most fish spawning and rearing streams with bankfull or characteristic discharges between 1-1000 m^3/s, the relationship is summarized as width = $4.5\ Q^{0.5}$ (Newbury 1998). Using this relationship[12], the historical bankfull width of China Creek is estimated to be approximately 7 meters.

[12] Relationships such as these can be utilized since the average channel dimensions and bankfull discharges are similar for streams of a given drainage area for similar geographic regions.

References

Alexander, Don and Hilda McKenzie. 1999. Trail-Blazing in False Creek: Building a heritage pathway is one way to link community, history and ecology. Alternatives Journal 25(2): 22-29.

Arnold C., P. Boison and P. Patton. 1982. Sawmill Brook: an example of rapid geomorphic change related to urbanization. Journal of Geology 90: 155-166.

Arnold, C. and C. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association. 62(2): 243-258.

Arnstein, S.R. 1969. A Ladder of Citizen Participation. Journal of the American Institute of Planners. July: 216-224.

Beatley, Timothy. 1999. Green Urbanism: Learning from European Cities. Island Press.

Beaulieu, James. 1990. The Provincial Interest in the Winnipeg Region's Rivers. Pages 9-11 *in* Towards Stewardship of Winnipeg's River Corridors: Conference Proceedings. Occasional Paper 20. Institute of Urban Studies, Winnipeg Manitoba.

Bedient, P.B. and W.C. Huber. 1992. Hydrology and Floodplain Analysis. Reading, Mass. Addison-Wesley.

Bescheta, Robert and William Platts. 1986. Morphological Features of Small Streams: Significance and Function. Water Resources Bulletin 22(3): 369-379.

Bingham, G. 1986. Resolving environmental disputes: A decade of experience. The Conservation Foundation, Washington, D.C.

Bjornn T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Pages 83-138 *In* W.R. Meehan (editor). Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19.

Booth D.B. 1990, Stream-channel incision following drainage-basin urbanization: Water Resources Bulletin, v. 26, pp. 407-417.

Booth D.B. 1991, Urbanization and the Natural Drainage System--Impacts, Solutions, and Prognoses: Northwest Environmental Journal, v. 7, p. 93-118.

Booth, D.B. 1998. Are wild salmon runs sustainable in rehabilitated urban streams? Salmon in the City Conference Proceedings, Mount Vernon, Washington.

Botelho, Zita. 1998. Community Stream Stewardship: Partnerships and Local Governance for Ecological Restoration. Pages 64-66 in Proceedings of the Helping The Land Heal Conference, Victoria B.C.

Brenneis, Kim and Michael M'Gonigle. 1991. Public Participation: Components of the Process. Environments 21(3):5-11.

British Columbia Round Table on the Environment and the Economy. 1994. State of Sustainability: Urban Sustainability and Containment. Victoria BC.

Brown, Meredith A. 1999. China Creek: Past, Present and Future? A preliminary feasibility study on the daylighting of China Creek in East Vancouver. Unpublished report for the Steelhead Society Habitat Restoration Corporation and Fisheries Renewal B.C.

Burton Jean. 1995. A Practical Approach to Integrated River Basin Management. Ecodecision. Summer 1995: 27-30.

Cairns, John, Jr. 1997. Eco-Societal Restoration: Creating a harmonious future between human society and natural systems. Pages 487-499 in J.E. Williams, C.A. Wood and M.P. Dombeck, editors. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Calow, P. and G. Petts. 1992. The rivers handbook: hydrological and ecological principles, volume 1. Blackwell Scientific Publications, Inc., Cambridge, Massachusetts.

Change H.H. 1988. Fluvial Processes in River Engineering. Wiley, New York.

City of Bellevue. 2000. Bellevue's Efforts to Save Salmon [online] URL: http://www.ci.bellevue.wa.us/utilities/surface/salmonefforts.htm

City of Vancouver. 1995. Vancouver Greenways Plan.

Claytor, R.A. 1995. Assessing the Potential for Urban Watershed Restoration. Watershed Protection Techniques 1(4): 166-172.

Community Stewardship: A Guide to Establishing your Own Group. The Stewardship Series, Co-produced by the Canadian Wildlife Service, Department of Fisheries and Oceans Canada, the Fraser Basin Management Program and Forest Renewal BC. 1995.

Cowx, I. and R. Welcomme (eds). 1998. Rehabilitation of Rivers for Fish. The Food and Agriculture Organization of the United Nations.

Curran, Deborah. 1999. Environmental Stewardship and Complete Communities: A Report on Municipal Environmental Initiatives in British Columbia. Report Series R99-6. Eco-Research Chair of Environmental Law & Policy, University of Victoria, Canada.

Dixon, J.A. and K.W. Easter. 1986. Integrated Watershed Management: an approach to resource management.

Dobson, Charles. 1995. The Citizen's Handbook: A guide to building community in Vancouver. City of Vancouver Social Planning.

Dovetail Consultants. 1995. Navigating for Sustainability: A Guide for Local Government Decision-Makers. Co-produced by the Fraser Basin Management Program, the Georgia Basin Initiative, the Ministry of Municipal Affairs, the Ministry of Small Business, Tourism and Culture and the BC Urban Salmon Habitat Program.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman, San Francisco.

EBA Environmental Limited. 1992. Investigation of Sources and solutions for Fecal Coliform Contamination in Trout Lake, BC. A report for the City of Vancouver Board of Parks and Recreation. Project No. 0806-86124.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes, and Practices. U.S.A.

Frissel, C.A. and R. K. Nawa. 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management 12(1): 182-197.

Furniss M.J., T.D. Roelofs, and C.S. Yee. 1991. Road Construction and Maintenance. Pages 297-323 In W.R. Meehan (editor). Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19.

Galli, J. 1990. Thermal impacts associated with urbanization and stormwater management best practices. Metro. Wash. Counc. Gov., Maryland Dept. Environment. Washington, D.C.

Galloway, Liz. 1996. Partnerships in Restoration. In Conference Proceedings of River Restoration '96. Silkeborg, Denmark. Pages 264-266.

Girling, C. and K. Helphand. 1997. Retrofitting Suburbia. Open space in Bellevue, Washington, USA. Landscape and Urban Planning 36: 301-313.

Greater Vancouver Regional District (GVRD). 1999. Combined Sewer Overflows. [online] URL: http://www.gvrd.bc.ca/sewers/bro/wwcso.html

Hammer T.R. 1972. Stream channel enlargement due to urbanization. Water Resources Research 8:1530-1540.

Havinga, Donna. 1999. Beyond Repair: Ecological restoration is as much about transforming values and practices as about repairing damaged ecosystems. Alternatives Journal 25(2): 14-17.

Helfield, J.M. and M.L. Diamond. 1997. Use of Constructed Wetlands for Urban Stream Restoration: A Critical Analysis. Environmental Management 21(3): 329-341.

Hobbs, R.J. and D.A. Norton. 1996. Towards a Conceptual Framework for Restoration Ecology. Restoration Ecology 4(2): 93-110.

Holling, C.S. 1978. Adaptive Environmental Assessments and Management. John Wiley and Sons, London, England.

Hollis, F. 1975. The effects of urbanization on floods of different recurrence intervals. Water Resources Research 11: 431-435.

Horner, Richard and Christopher May. 1998. Watershed Urbanization and the Decline of Salmon in Puget Sound Streams. Salmon in the City Conference Proceedings, Mount Vernon, Washington.

Houck, Mike. 1996. Restoring Urban Watersheds: Portland's Rapidly Growing Neighbourshed Movement. [online] URL: http://www.tnews.com/text/neighborshed.html

Hough, Michael. 1984. City Form and Natural Process. U.K. Croom Helm.

Hurley, Karen. 1998. Setting Priorities for Restoration within Limited Resources – A Municipal Experience. Pages 231-232 In Proceedings of the Helping The Land Heal Conference, Victoria B.C.

Hynes H.B.N. 1970. The Ecology of Running Waters. Liverpool University Press, Liverpool.

Jones, Daniel R. and Mark Battaglia. 1989. Main Street Rivers: Making Connections Between Rivers and Towns. The Pennsylvania State University Department of Landscape Architecture.

Kaner, Sam, Lenny Lind, Catherine Toldi, Sarah Fisk and Duane Berger. 1996. Facilitator's Guide to Participatory Decision-Making. New Society Publishers, Gabriola Island, B.C.

Kaplan, Rachael, Stephen Kaplan and Robert Ryan. 1998. With People in Mind: Design and Management of Everyday Nature. American Society of Landscape Architects. Island Press.

Karr, J. and I. Schlosser. 1977. Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota. U.S. Environmental Protection Agency.

Kellerhals, Rolf and Michael Miles. 1996. Fluvial Geomorphology and Fish Habitat: Implications for River Restoration. Pages A261-A279 In Leclerc M. (ed.), Proceedings of the second IAHR Symposium on Habitat Hydraulics. Ecohydraulics 2000.

Klein, R.D. 1979. Urbanization and Stream Quality Impairment. Water Resources Bulletin 15: 948-963.

Kondolf, G. Mathias. 1996. River Restoration in California: lessons learned. Pages 213-216 In Conference Proceedings of River Restoration '96. Silkeborg, Denmark.

Lampe, L., H. Andrews and K. Kisinger. 1996. 10 Issues in urban stormwater pollution control. American City and County, Vol. 3(10): 36-53.

Leccese, M. 1996. A River Reborn. Landscape Architecture 86(6): 36-41.

Leopold, L.B. 1968. Hydrology for urban land planning: a guidebook on the hydrologic effects of land use. Reston (VA): US Geological Survey. Circular no. 554.

Leopold L.B., Wolman M.G. & Miller J.P. 1964. Fluvial Processes in Geomorphology. Freeman, San Francisco.

Lessard, G. 1998. An Adaptive Approach to Planning and Decision-Making. Landscape and Urban Planning 40: 81-87.

Lienkaemper G.W. and F.J. Swanson. 1987. Dynamics of large woody debris in streams in old-growth Douglas-fir forests. Can. J. For. Res. 17: 150-156.

Little, C.E. 1990. Greenways for America. Baltimore: The John Hopkins University Press.

Luchetti G. and R. Fuersteburg. 1993. Relative fish use in urban and non-urban streams. Conference Proceedings Wild Salmon. Vancouver, B.C.

Mackenzie, F.B. 1987. Urbanization and the Hydrological Regime. Pages 277-293 In M.C. Healey and R.R. Wallace editors, Canadian Bulletin of Fisheries and Aquatic Sciences 215. .

Malcom, H.R. and C.C. Lancaster. 1991. Levels of Service Applied to Urban Streams. Journal of Water Resources Planning and Management, Vol. 117 (4): 482-497.

Marshall, David. 1998. Watershed Management in British Columbia: The Fraser Basin Experience. Environments 25(2&3): 64-79.

McBain, S. and B. Trush. 1997. Thresholds for managing regulated river ecosystems. Pages 11-13 In S. Sommarstrom (ed.), Proceedings, Sixth Biennial Watershed

Management Conference, Water Resources Center Report No. 92, University of California Davis.

McGurrin, J. and H. Forsgren. 1997. What Works, What Doesn't, and Why. Pages 459-471 In J.E. Williams, C.A. Wood and M.P. Dombeck, editors. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Millar, John, Matthew Child, Lorna Duncan, Nick Page, Debbie Modien and Jennifer Robertson. 1997. Urban Referral Evaluation: An Assessment of the Effectiveness of the Referral Process for Protecting Fish Habitat. Prepared for the Ministry of Environment, Lands and Parks and the Department of Fisheries and Oceans, Vancouver, BC.

Mitchell, B. and D. Shrubsole. 1994. Canadian Water Management: Visions for Sustainability. Canadian Water Resources Association, Cambridge, ON.

Morris, S.E. 1995. Some Geomorphic Aspects of Stream Restoration. Physical Geography 16(5): 444-459.

Morrison, S.W. 1988. The Percival Creek Corridor Plan. Journal of soil and water conservation 43(6): 465-471.

Muhar, S., S. Schmutz & M. Jungwirth. 1995. River Restoration Concepts – Goals and Perspectives. Hydrobiologia 303: 183-194.

Naiman, R.J., H. DeCamps and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3(2): 209-212.

National Research Council (NRC). 1992. Restoration of aquatic ecosystems: science, technology, and public policy. National Academy Press, Washington, D.C.

Newbury, R.W. 1998. Stream Hydraulics Notes. Stream Restoration Design Workshop, Chapman Creek, BC.

Newbury, R.W., M. Gaboury, and C. Watson. 1998. Field Manual of Urban Stream Restoration. Illinois State Water Survey. Champaign, Illinois.

Newbury, R.W. and M.N. Gaboury. 1993. Exploration and rehabilitation of hydraulic habitats in streams using principles of fluvial behaviour. Freshwater Biology 29, 195-210.

Newbury, R.W., and M.N. Gaboury. 1994. Stream Analysis and Fish Habitat Design: a Field Manual, 2nd ed. Newbury Hydraulics, Gibsons, BC.

Newbury, R.W, M.N. Gaboury and D. Bates. 1996. Constructing Riffles and Pools in Channelized Streams. In Conference Proceedings of River Restoration '96. Silkeborg, Denmark.

Newman, Peter. 1996. Greening the City: The ecological and human dimensions of the city can be part of town planning. Alternatives Journal 22(2):10-16.

Nunnally Nelson R. 1985. Application of Fluvial Relationships to Planning and Design of Channel Modifications. Environmental Management Vol. 9(5): 417-426.

O'Meara, Molly. 1999. Reinventing Cities for People and the Planet. Worldwatch Paper 147.

Ontario Ministry of Natural Resources. 1994. Natural Channel Systems: An Approach to Management and Design. Queens Printer for Ontario.

Pastorok, R., A. MacDonald, J. Sampson, P. Wilber, D. Yozzo, and J. Titre. 1997. An ecological decision framework for environmental restoration projects. Ecological Engineering 9: 89-107.

Pederson, Eric. 1999. The Garrison Creek Linkage Plan: A model for developing an open-space system. Plan Canada 39(5): 20-21.

Pederson, E. and M. Perkins. 1986. The use of benthic invertebrate data for evaluating impacts of urban runoff. Hydrobiologia 139: 13-22.

Planning Ourselves In Group. 1994. Planning ourselves in: women and the community planning process: a tool kit for women and planners. Vancouver, B.C .

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime: A paradigm for river conservation and restoration. BioScience 47(11):769-784.

President's Council on Sustainable Development. 1997. Sustainable Communities Task Force Report. Washington, DC.

Proctor, S.J. (ed.). 1989. Vancouver's Old Streams. Vancouver Public Aquarium Association. Vancouver, B.C.

Quayle, Moura. 1992. Greenways, public ways. Final report of the Urban Landscape Task Force. City of Vancouver, BC.

Riley, Anne L. 1994. The Greening of Federal Flood-Control Policies: The Wildcat-San Pablo Creeks Case. Pages 217-230 In Platt, Rutherford H., A. Rowntree, and Pamela Muick, editors. The Ecological City: Preserving and Restoring Urban Biodiversity.

Riley, Anne L. 1998. Restoring Streams in Cities; A Guide for Planners, Policymakers, and Citizens. Island Press, Washington, D.C.

Romaine, M.J. and T. E. Romaine. 2000. An Assessment of Barriers and Proposed Actions to Advance Watershed Management in British Columbia. A Report on Community Workshops for the British Columbia Watershed Stewardship Alliance.

Rood, K.M. and R.E. Hamilton. 1994. Hydrology and Water Use for Salmon Streams in the Fraser Delta Habitat Management Area, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2038.

Roseland, Mark, ed. 1997. Eco-City Dimensions: Healthy Community, Healthy Planet. Gabriola Island: New Society Publishing.

Roseland, Mark. 1998. Toward Sustainable Communities. Gabriola Island: New Society Publishing.

Saunders Todd. 1996. Ecology and Community Design: Lessons from Northern European Ecological Communities. Alternatives Journal 22(2): 24-29.

Schaffer, Barbara and Bronwyn Maelzer. 1997. Restoring the Waters Project. Unpublished report for The Australian Conservation Foundation.

Schagrin, Adrian. 1997. Restoring streams key in city's stormwater work. The American city and county, Vol. 112: 78.

Scheuler, Tom. 1992. Mitigating the adverse impacts of urbanization on streams: A comprehensive strategy for local government. Pages 21-31 In The Watershed Restoration SourceBook. Prepared by the Anacostia Restoration Team, The Department of Environmental Programs, The Metropolitan Washington Council of Governments.

Schueler, Tom. 1995a. Site Planning for urban Stream Protection. Centre for Watershed Protection. Metropolitan Washington Council of Governments. Silver Spring, MD.

Schueler, Tom. 1995b. The importance of imperviousness. Watershed Protection Techniques 1(3): 100-111.

Schueler, Tom. 1996. Crafting Better Urban Watershed Protection Plans. Watershed Protection Techniques 2(2): 329-337.

Sheltair Group Inc. 1998. Visions, Tools and Targets: Environmentally Sustainable Development Guidelines for Southeast False Creek. A report prepared for Central Area Planning, City of Vancouver.

Shepp, David L. and James D. Cummins. 1997. Restoration in an Urban Watershed: Anacostia River of Maryland and the District of Columbia. Pages 297-317 In J.E. Williams, C.A. Wood and M.P. Dombeck, editors. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Shindler, B. and K. Aldred Cheek. 1999. Integrating citizens in adaptive management: a prepositional analysis. Conservational Ecology 3(1): 9 [online] URL: http://www.consecol.org/vol3/iss1/art9

Simmons, D. and R. Reynolds. 1982. Effects of urbanization on baseflow of selected south shore streams, Long Island, NY. Water Resources Bulletin 18(5): 797-805.

Slaney, P.A. and A.D.Martin. 1997. The Watershed Restoration Program of British Columbia: Accelerating Natural Recovery of Processes. Water Qual. Res. J. Canada 32(2): 325-346.

Slaney, P.A. and D. Zaldokas (eds.). 1997. Fish Rehabilitation Procedures. Watershed Restoration Technical Circular No. 9. The Watershed Restoration Program.

Slocombe, D.S. 1993. Environmental Planning, Ecosystem Science, and Ecosystem Approaches for Integrating Environment and Development. Environmental Management 17(3): 289-303.

Society for Ecological Restoration. 1994. "Definitions", Society for Ecological Restoration News, Fall 1994.

Steedman, R. J. 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in Southern Ontario. Can. J. of Fisheries and Aquatic Sci. 45: 492-501.

Stewart, Greg. 1998. Grandview Greenway: An investigation of ecological enhancement and stormwater management as a means of connection in an urban environment. Unpublished Masters Thesis. The Faculty of Agricultural Sciences, Landscape Architecture Program. University of British Columbia.

Task Force to Bring Back the Don. 1991. Bringing Back the Don. Prepared by the Planning and Development Department of the City Hall, Toronto, Ontario.

The Outdoor Recreation Council of BC. 1998. BC's Ten Most Endangered Rivers Of 1998 [online] URL: http://www.out-there.com/orc.htm#Ten

Thom, R.M. and K.F. Wellman. 1997. Planning Aquatic Ecosystem Restoration Monitoring Programs. IWR Report 96-R-23. U.S. Army Corps of Engineers, Institute for Water Resources, Alexandria, Virginia.

Tilt, Whitney and Cindy Williams. 1997. Building Public and Private Partnerships. Pages 145-157 In J.E. Williams, C.A. Wood and M.P. Dombeck, editors. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Trauger, D.L., W. Tilt, and C.B. Hatcher. 1995. Partnerships: innovative strategies for wildlife conservation. Wildlife Society Bulletin 23(1): 114-119.

Trout Lake Restoration Committee. 1995. Background Papers. Unpublished Report of the Committee.

Turner, William M. 1999. Integrating the Private Sector into Watershed Restoration Programs. Unpublished report for the Missouri Department of Conservation, Sedalia, MO.

Urban Land Institute. 1998. Smart Growth: Economics, Community, Environment. Washington, D.C.

U.S. Environmental Protection Agency. 1990. Environmental Monitoring and Assesment Program, ecological Indicators. EPA/600/3-90/060. Hunsaker, C.T., Carpenter D.E. (Eds.). U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Warner, Andrew. 1996. Developing an Applied System of Ecological Indicators for Measuring Restoration Progress in an Urban Watershed. In Conference Proceedings of Watershed '96: Moving Ahead Together. Baltimore, Maryland.

J.E. Williams, C.A. Wood and M.P. Dombeck, editors. 1997. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Wood, C.A., J.E. Williams and M.P. Dombeck. 1997. Learning to live within the limits of the land: lessons from the watershed restoration case studies. Pages 445-458 In J.E. Williams, C.A. Wood and M.P. Dombeck, editors. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Wu, Kenneth and Meredith Flannery. 1996. An ecological survey and conservation assessment of Vancouver's Grandview Cut. Unpublished report for the Environmental Youth Alliance, Vancouver, BC.

Wyant, J.G., R.A. Meganck and S.H. Ham. 1995. A Planning and Decision-Making Framework for Ecological Restoration. Environmental Management 19(6): 789-796.