STONEY CREEK STORMWATER STEERING COMMITTEE

INTEGRATED STORMWATER MANAGEMENT STRATEGY FOR STONEY CREEK WATERSHED

FINAL DRAFT FOR PUBLICATION

FEBRUARY 1999

CGS File No. 112V25464
KWL File No. 1045.002D

KERR WOOD LEIDAL - CH2M HILL INC
A Jointly Owned Company of CH2M Gore & Storrie Ltd. and Kerr Wood Leidal Associates Ltd.

TABLE OF CONTENTS

5. RESULTS OF AQUATIC HABITAT ASSESSMENT

6. RESULTS OF RUNOFF QUALITY MONITORING

7. CONCEPT PLANNING FOR INTEGRATED STORMWATER MANAGEMENT

8. SUMMARY AND RECOMMENDATIONS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

Follows
Page No.

DEFINITIONS AND ABBREVIATIONS

DEFINITIONS AND ABBREVIATIONS

This page of definitions and abbreviations has been included to provide the reader with a roadmap regarding key concepts that are presented in this report.

Integrated Stormwater Management	Considers all the rainfall events that comprise the annual runoff hydrograph, and comprises two distinct components: hydrotechnical and environmental
Hydrotechnical Component	Focus is on property protection. Addresses dramatic impacts associated with the infrequently occurring big storms
Environmental Component	Focus is on ecosystem protection. Addresses the insidious impacts of the frequently occurring storms on stream banks and aquatic habitat
Small Storms	Defined as those that occur on a frequent basis (say 6 to 10 times yearly)
Big Storms	Defined as those that occur infrequently (say 5-year return period and greater)
MDP	Master Drainage Plan
MDP Level	A concept for defining strategic objectives and identifying management practices to achieve those objectives
TIA	Total Impervious Area: The fraction of a watershed covered by constructed, non-infiltrating surfaces (such as concrete, asphalt and buildings)
EIA	Effective Impervious Area: The fraction of a watershed covered by constructed, non-infiltrating surfaces having a direct hydraulic connection to the downstream drainage (or stream) system
LWMP	Liquid Waste Management Plan
BMPs	Best Management Practices: Physical, structural and management practices that prevent or reduce water pollution and changes in hydrology

CONTENTS OF EXECUTIVE SUMMARY

LIST OF TABLES

Follows
Page No

LIST OF FIGURES

Follows
Page No

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

THE CHALLENGE

The Stoney Creek watershed is described as the tributary sub-system having the best environmental values within the Brunette River Basin. The land use patterns are well-established, and the watershed is substantially developed, especially in the eastern half. Figure A is an air photo mosaic that shows the extent and nature of the drainage area.

The only forested land still to be developed is located within the Ring Road at Simon Fraser University. The forested mountainside below the Ring Road is being preserved as parkland. In the existing urban areas, the watershed is beginning to undergo redevelopment. This trend is expected to continue in the coming decades.

The *Brunette Watershed Management Plan* provides the over-arching framework for development of a comprehensive stormwater management strategy for the Stoney Creek sub-system. This poses a considerable challenge in that it is a balancing act to protect property and allow economic land use while sustaining natural systems, especially when a major portion of the drainage area is situated on a mountainside.

OVERVIEW OF STUDY ACCOMPLISHMENTS

Through a series of workshops and working sessions with the *Stoney Creek Steering Committee* over a 6-month period, the Stoney Creek study process has involved a participatory process to facilitate consensus-building as to what may be achievable for ecosystem protection and enhancement in conjunction with stormwater management.

The study components and Committee members are identified in Table A. The Committee provided invaluable input to the plan development process, and helped guide the project team in the development of recommendations especially related to the aquatic and water quality components.

Given the diverse background of the Steering Committee, it was essential to develop a common understanding of fundamental concepts. This was accomplished by means of a graphic that illustrates the consequences for stream corridor ecology as a function of the choice of MDP (Master Drainage Plan) level. This decision-making tool conceptualized six *MDP Levels* that capture the evolution of drainage planning philosophy over the decades. This tool facilitates selection of a guiding philosophy.

The concept of *MDP Levels* represents a significant advancement in stormwater management because it provides a framework for defining strategic objectives, and identifying management practices for achieving those objectives. Figure B illustrates the six levels, and provides a benchmark for decision-making

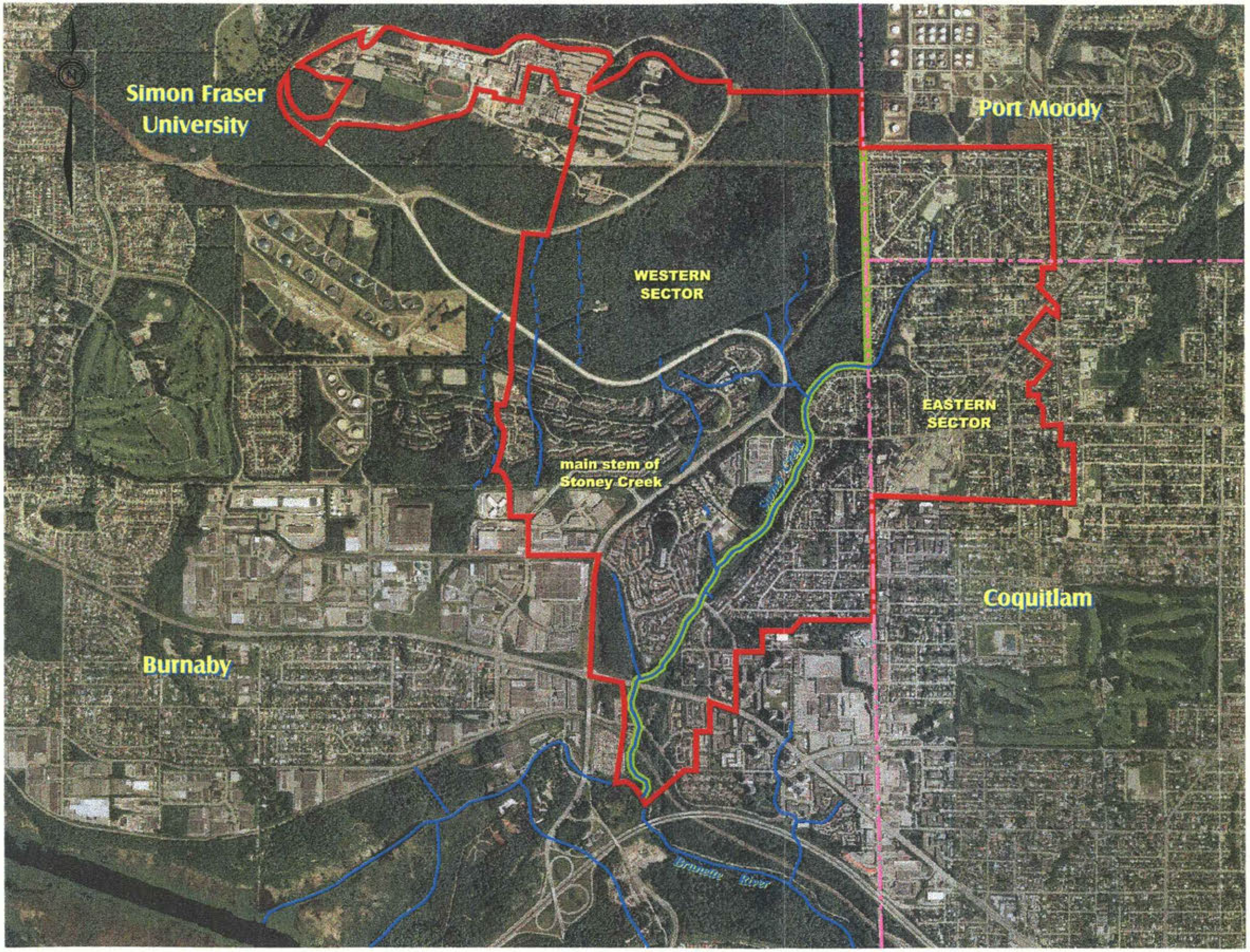
The key deliverable resulting from this study is Table B because it presents a comprehensive framework for action to initially 'hold the line' (*Level 3 MDP),* and then over time 'improve conditions' *(Level 4 MDP)* in the Stoney Creek watershed to achieve the Brunette Vision for a sustainable environment.

TABLE A

**SCOPE OF WORK PROGRAM
FOR DEVELOPMENT OF AN INTEGRATED STORMWATER
MANAGEMENT STRATEGY**

PART	DESCRIPTION	SCOPE OF COMPONENT
A	Storm Runoff Control	The focus was on mitigating flood and erosion damage resulting from peak flows during major storm/runoff events (i.e., Q_{10} and Q_{100})
B	Aquatic Habitat Protection and Enhancement Evaluation	This involved development of a strategy for ensuring the *environmental health* of major streamside resources, including both riparian and in-stream habitat.
C	Runoff Quality Control	The focus was on water quality for aquatic life, with particular emphasis on developing guidelines for the preservation of water quality in Stoney Creek for fish habitat.
D	Consensus-Building	This involved working with the Steering Committee to develop a shared vision regarding the goals and objectives for watershed and stream corridor management.

Membership for Stoney Creek Steering Committee	
Name	**Organization**
Steering Committee	
Lambert Chu, Chair	Engineering Department, City of Burnaby
Susan Haid	Planning Department, City of Burnaby
Kevin Connery	Planning Department, City of Burnaby
David Palidwor	Parks department, City of Coquitlam
Julie Pavey	Environmental Services, City of Port Moody
Ed von Euw	Greater Vancouver Regional District
Caroline Berka	Greater Vancouver Regional District
Ken Hall	Westwater Centre, University of B.C.
Bob Brown	Simon Fraser University
Bob Gunn	B.C. Institute of Technology
Jennifer Atchison	Stoney Creek Environmental Committee



LEGEND

Drainage Area Boundary

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

500 250 0 500

Scale in Metres

PROJECT No.	DATE:
1045-002	JULY 28, 1998

STONEY CREEK STUDY AREA

FIGURE A

FACTORS LIMITING THE ECOLOGICAL VALUES OF URBAN STREAMS

Recent research on urban streams has indicated that the four primary factors affecting the ecological values of urban streams are, in order of importance, as listed below:

- Changes in hydrology
- Disturbance of the riparian corridor
- Disturbance of aquatic habitat
- Deterioration of water quality

Understanding these factors provides a basis to develop guiding principles for an integrated approach to stormwater and stream corridor management. These four factors provided the 'roadmap' for crystallizing a set of three scenarios corresponding to various levels of environmental protection, specific objectives to achieve the results, measurable criteria to test achievement, and actions needed to achieve the desired results.

COMPREHENSIVE FRAMEWORK FOR STORMWATER MANAGEMENT

Building on this understanding, Table B is a matrix that correlates the four *limiting factors* with the mitigation measures needed in each of the three basic management units that comprise the Stoney Creek watershed, namely: the Western Sector Drainage Area, the Main Stem (of Stoney Creek itself), and the Eastern Sector Drainage Area.

Table B synthesizes key findings from the report. Furthermore, it integrates the hydrotechnical and environmental components of the stormwater management strategy, and provides the framework for implementation of an *Action Plan*.

A fundamental concept is that of 'total' versus 'effective' impervious area (i.e. *EIA versus TIA*) because of the impacts resulting from consequent *changes in hydrology;* and the inter-relationships with aquatic habitat and water quality degradation. The EIA concept is elaborated on in the page following.

INTEGRATION OF COMPONENT PLANS FOR RISK MANAGEMENT

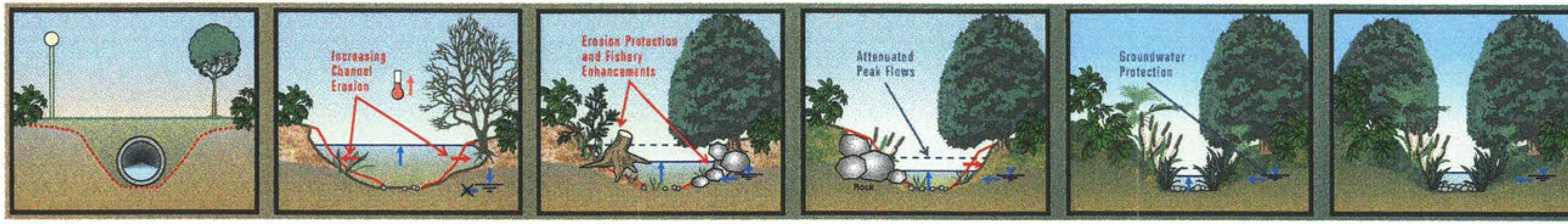
The strategy for integrated stormwater management comprises component plans for *flood risk management* and *environmental risk management*. The purpose of the former is to protect property by ensuring that the 'design flood' can be contained by creek channels and passed by culverts; whereas the latter protects stream corridor ecosystems from being degraded by the insidious consequences of frequently occurring small storms. Both components are highlighted on Table B. Each has spinoff benefits in terms of the other components (as noted in Table B).

Before anything can happen in terms of 'holding the line' (Level 3) and over time 'improving conditions' (Level 4) in Stoney Creek, there needs to be a political will to make something happen. For this reason, choices are presented and a series of decision points are identified to guide the political process.

ALTERNATIVE VISIONS FOR THE LONG-TERM ENVIRONMENTAL HEALTH OF STREAM CORRIDORS

Conceptual Framework For Selection Of Master Drainage Plan (MDP) Level

PLANNING LEVEL	1	2	3	4	5	6
GOAL OF MASTER DRAINAGE PLAN	*Protect Property* (1960s)	*Mitigate Major Storms* (1980s)	*Preserve Aquatic Habitat* (1990s)	*Improve Aquatic Habitat*	*Restore Aquatic Habitat*	*Restore Entire Watershed*
CONDITION OF STREAM CORRIDOR						
BIODIVERSITY AND ABUNDANCE	*Eliminated* ←	*Decreased* ←	*No Further Loss* →	*Enhanced* →	*Increased* →	*Fully Restored*
COMMUNITY VISION	NOT ACCEPTABLE		RETROFIT STREAM STEWARDSHIP			NOT ACHIEVABLE



AFFORDABILITY THRESHOLD ?
(Community Willingness To Pay)

This figure demonstrates how to apply Figures 1 and 2 as a management tool for descision-making. It illustrates the consequences for stream corridor ecology as a function of the choice of MDP level.

FIGURE B

KWL–CH2M
CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

1045-002/FIGB-EXE.CDR

ACHIEVABLE GOALS FOR ENVIRONMENTAL PROTECTION

Table B is the key deliverable in this report because it establishes specific goals for each management unit within the context of:

- the over-arching framework provided by the *Brunette Vision;*
- the overall goals for the study area; and
- the time-line concept for achieving those goals.

Furthermore, Table B correlates the goals with EIA to provide a target level for mitigating *changes in hydrology* and preventing *water pollution*. Since the EIA indicator is the key element shaping the strategy and direction for the Stoney Creek watershed, it is important to provide the following understanding:

- **Consequences of Changes in Hydrology:** Replacement of native ground cover with impervious surfaces results in an increased frequency of occurrence of threshold levels of runoff from 'small storms', and this in turn triggers watercourse erosion and sedimentation processes that then degrade or eliminate aquatic/riparian habitat.

- **Total Impervious Area (TIA):** The fraction of the Stoney Creek watershed covered by constructed, non-infiltrating surfaces (such as concrete, asphalt and buildings) is 29%.

- **Effective Impervious Area (EIA):** EIA is defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system, and therefore excludes some paved surfaces that may contribute nothing to the storm-runoff response of the downstream system. (For Stoney Creek, it is estimated that the EIA is approximately 80% of the TIA, and is therefore about 23%).

Most urban watersheds in the Pacific Northwest eco-region may be unable to sustain *abundant self-supporting* populations of cold water fish once the TIA exceeds 30%. The Stoney Creek ecosystem still supports spawning and rearing populations of coho and steelhead trout, as well as resident and sea-run cutthroat trout; with the presence of steelhead and anadromous cutthroat trout being particularly significant because of their rare occurrence in urban streams.

Achieving the overall goal of 'holding the line' (*Level 3 MDP)* means implementing measures that prevent the EIA from exceeding the 1998 level of 23%. Achieving the overall goal of 'improving conditions' (*Level 4 MDP*) means reducing the EIA below the 20% threshold.

Measures to achieve these goals would comprise a combination of on-site stormwater detention, on-site impervious area reduction, flow diversion around high value creek reaches, and regional detention. Diversion and detention would represent a fallback position if on-site measures were not effective in achieving the target EIA level.

Again, it must be emphasized that mitigating *changes in hydrology* would reduce pollutant loading, and thereby have a beneficial impact on water quality.

TABLE B

COMPREHENSIVE STRATEGY FOR STORMWATER MANAGEMENT AND ECOSYSTEM PROTECTION IN THE STONEY CREEK WATERSHED

GOALS AND RANKING❶❷	WESTERN SECTOR DRAINAGE AREA		MAIN STEM (UP TO NORTH ROAD)		EASTERN SECTOR DRAINAGE AREA	
	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)
	Maintain EIA at '98 Level of 29%❷	Reduce EIA Below 20%	Maintain EIA at '98 Level of 23%	Reduce EIA Below 20%	Maintain EIA at '98 Level of 31%	Reduce EIA Below 20%
Hydrology	For new development and/or redevelopment, mitigate changes in hydrology by providing a combination of: ➢ on-site stormwater detention ➢ impervious area reduction ➢ off-site diversion and detention	For existing development and/or re-development, mitigate the frequently occurring storms by a combination of: ➢ on-site detention ➢ impervious area reduction ➢ a regional detention facility at a site in the vicinity of the Cariboo Dam	➢ For new development and/or redevelopment in watershed, provide a combination of on-site detention and impervious area reduction ➢ replace culverts with "bridged" crossings	For existing development in watershed, intercept runoff from the frequently occurring events and divert to the regional ponds	For re-development, mitigate changes in hydrology (due to land use densification) by providing a combination of: ➢ on-site detention ➢ impervious area reduction	For existing development and/or re-development, mitigate the frequently occurring storms by a combination of: ➢ impervious area reduction ➢ on-site detention ➢ regional detention facilities at two locations
Riparian Corridor	For the three tributaries: ➢ re-plant disturbed portions of corridors to restore native vegetation ➢ Ensure "no net loss" of riparian buffer width or vegetation	For the three tributaries: ➢ consider acquiring additional right-of-way width (in conjunction with future land re-development) if required to achieve possible greenway objectives ➢ increase the "effective width" of undisturbed vegetation to a minimum 30 m (each side) for at least 60% of corridor length	➢ re-plant disturbed portions of the corridor to restore native vegetation ➢ re-develop a trail system that achieves a balance between human access and fish protection ➢ mitigate the impact of the existing GVRD access road	➢ consider acquiring additional right-of-way width (in conjunction with future land re-development) to achieve possible greenway objectives ➢ increase the "effective width" of undisturbed vegetation to minimum 50 m (each side) for at least 60% of corridor length	For Main Stem above North Road (i.e. in Coquitlam and Port Moody) ➢ develop a partnership with the local community to foster awareness of ecosystem values ➢ ensure "no net loss" of riparian buffer width or vegetation	For Main Stem above North Road (i.e. in Coquitlam and Port Moody) ➢ consider acquiring ownership of a *Riparian Habitat Buffer Zone* (for 30m minimum each side of channel) in conjunction with future land redevelopment ➢ re-establish native vegetation within the buffer strip for at least 60% of the corridor length
Aquatic Habitat	For the three tributaries: ➢ through the volunteer Streamkeepers Program, continue to implement in-stream improvements as identified by the SCEC and as validated through the Steering Committee process ➢ rehabilitate culverts to minimize barriers to fish passage❺	For the three tributaries: ➢ place the highest priority on protecting and enhancing Tributary #3 ➢ identify opportunities to recreate physical habitat through an aggressive program of channel improvements along full length ➢ replace culverts with "bridged" crossings to eliminate barriers and enable fish passage to upstream habitat	➢ for new development and/or redevelopment in watershed, provide a combination of on-site detention and impervious area reduction ➢ through the volunteer Streamkeepers Program, continue to implement in-stream improvements ➢ replace culverts with "bridged crossings	➢ intercept runoff from the frequently occurring events and divert to the regional ponds ➢ recreate physical habitat through side-channel construction and/or main channel improvements ➢ achieve a pool/riffle ratio of approximately 50/50 ➢ utilize benthic monitoring to locate and mitigate sources of degradation	For Main Stem above North Road ➢ through the voluntary Streamkeepers Program, and in partnership with local landowners, identify potential opportunities for habitat enhancement and where possible implement minor channel improvements for resident fish	For Main Stem above North Road ➢ through a partnership initiative with local landowners, consider recreating resident fish habitat within the *Riparian Habitat Buffer Zone* ➢ investigate the feasibility of "daylighting" the channel in the upper reaches (i.e. through the school property)
Water Quality	For Burnaby only: ➢ invest in public education, maintenance management programs, and source control regulations ➢ review and update spill response procedures ➢ provide for spill containment (deleterious substances) at high risk locations	For Burnaby only: ➢ utilize the proposed regional detention facility for pollutant removal and/or treatment ➢ strive to comply with future Federal/Provincial/municipal guidelines for all quality parameters	➢ continue with sanitary sewer rehabilitation program to reduce exfiltration (and hence, coliform counts) ➢ stabilize erosion sites to minimize sediment loading	➢ intercept "first flush" runoff and divert to regional ponds ➢ strive to comply with future Federal/Provincial/municipal guidelines for all quality parameters	For all three municipalities: ➢ invest in public education, maintenance management programs, and source control regulations ➢ review and update spill response procedures ➢ provide for spill containment (deleterious substances) at high risk locations.	For all three municipalities: ➢ utilize the proposed regional detention facility at the Tributary #3 confluence for pollutant removal and/or treatment For Burnaby only: ➢ utilize the proposed regional detention facility near the Lougheed Highway for pollutant removal and/or treatment

Cost for Flood Risk Management (to protect property)	$0.6 M for storm sewer upsizing in Burnaby to prevent flood overflows that would otherwise cause property damage	-	➢ $5.0 M for culvert replacements in Burnaby❹ ➢ $0.5 M for culvert replacement at North Road❹			-
Cost for Environmental Risk Management (to protect ecosystems)	-	➢ $6.5 M for flow interception and detention/treatment in Burnaby❸ to partially restore natural hydrology and prevent water pollution	-	-	-	➢ $4.0 M for flow interception and detention/treatment to serve all three municipalities❸ ➢ $4.0 M for flow interception and detention/treatment to serve Burnaby❸

❶ Ranking based on results of research by the *Center for Urban Water Resources Management* at the University of Washington (Seattle), regarding the impacts of land use changes on the environmental health of urban streams.
❷ EIA = Effective Impervious Area. By definition, this is impervious surfaces with direct hydraulic connection to drainage or stream system. These are estimated values based on applying an 80% factor to TIA. For the overall watershed, computer model calibration resulted in a close correlation with the 23% level. For the Western Sector, and as decided in consultation with the Steering Committee, the EIA calculation excludes Burnaby Mountain Park. (Note: Including the park, the EIA is 17%).
❸ The investment in flow interception in the Eastern and Western Sectors would have a spin-off benefit for flood risk management in the Main Stem. The benefit would be in terms of the reduced potential for debris transport and blockage.
❹ The investment in culvert replacement would have a spin-off benefit for environmental risk management in the Main Stem by creating opportunities for habitat enhancement, and by reducing the potential for flood damage.
❺ All existing culverts on Tributary #1 and #2 are rated as inadequate from an environmental perspective, but are considered acceptable installations in terms of overall conformance with the *Guidelines for Effective Culvert Design*.

MITIGATING *CHANGES IN HYDROLOGY* AT THE SOURCE VERSUS OFF-SITE

The four factors limiting the ecological values of urban creeks provide a 'roadmap' for development of an integrated stormwater management strategy. Significantly, *changes in hydrology* can be viewed as the paramount factor because the consequences of those changes progressively manifest themselves in the disturbance of riparian and aquatic habitat, and in the deterioration of water quality.

Recognition of the need to address *changes in hydrology* is the first step on a journey that has a 50-year time horizon. Thus, implementing an holistic strategy that encompasses all four limiting factors requires commitment and perseverance. Achieving initial successes is key to building support for the long-term vision. Having a time-line as follows provides a reality-check and a focus for action:

MINIMUM TIME HORIZON	IDENTIFICATION OF MINIMUM GOALS
Within 20 years	The goal would be to reach *Level 3* (i.e. as an average condition)
After 20 to 50 years	Building on success in the first 20 years, strive for *Level 4* in the decades following

In mitigating 'changes in hydrology', the distinction between the two types of storm and runoff conditions needs to be emphasized:

- **Frequently Occurring Small Storms:** Under natural forested conditions, there is no runoff from small storms. Once land is urbanized, however, runoff results. And as the impervious percentage increases, there are an increased number of runoff events per year at or above a threshold level that results in watercourse 'wear-and-tear.'
- **Infrequently Occurring Large Storms:** Flood flows usually occur at the end of a prolonged wet-weather period when the pervious ground is fully saturated and contributing runoff. Thus, redevelopment of land to higher impervious percentages would only marginally increase the flood peak.

Roughly 90% of the annual rainfall events in the Greater Vancouver region have less than 2.5mm of rainfall. This is a manageable amount to infiltrate, provided there is a will to apply existing legislation to enact and enforce bylaws for regulation of impervious area at development sites. The alternative to source-control is to mitigate 'changes in hydrology' off-site in a regional detention system.

For Stoney Creek, the purpose of impervious area reduction and/or stormwater detention (whether on-site or off-site) is to mitigate the *frequently occurring storms* by partially restoring the natural hydrology. By addressing 'changes in hydrology' related to the small (or frequent) storms, the goal of 'environmental risk management' is ecosystem protection. Providing protection against the big (or infrequent) storms is the goal of 'flood risk management.'

Table C: Decision Criteria to Select Strategies for Stream Management

OBJECTIVES OR DECISION CRITERIA		HOW IMPORTANT IS EACH DECISION CRITERION?❶	HOW WELL DOES EACH SCENARIO ACHIEVE EACH OBJECTIVE?❷		
			SCENARIO A (LEVEL 2 MDP)	SCENARIO B LEVEL 3 MDP)	SCENARIO C (LEVEL 4 MDP)
NO.	AS ESTABLISHED BY THE BRUNETTE BASIN TASK GROUP		STATUS QUO, CONTINUED DECLINES IN FISH*	HOLD THE LINE, SUSTAIN TROUT AND HATCHERY SALMON*	STRATEGY C: ENHANCE HABITAT, SUSTAIN WILD SALMON*
1.	Protect or enhance biodiversity*	very important	low	medium	high
2.	Protect or enhance aquatic habitat*	very important	low	medium	high
3.	Protect or enhance terrestrial habitat	moderate importance	low	medium	high
4.	Enhance recreation opportunities	moderate importance	low	medium	high
5.	Minimize health and safety impacts	very important	high	high	high
6.	Minimize total costs❸	very important	high (no change in existing costs)	medium (increased costs)	low (high cost)
7.	Minimize property damage	very important	medium	high	high
8.	Increase scientific and management understanding	least important	medium	high	high
9.	Increase opportunity for public learning	least important	medium	high	high

* See Tables 3-1, 3-2 and 3-3 for refinement of these Decision Criteria and for more detailed descriptions of the scenarios.

❶ Based on the experience of the project team, three judgemental choices are provided for rating each objective: very important, moderate importance, and least important.

❷ Based on the experience of the Project Team, three judgemental choices are provided for rating each scenario: low, medium and high.

❸ By definition, "total costs" are based on present value analysis.

APPLICATION OF THE 6-STEP PROCESS FOR DECISION-MAKING

A proven 6-step process for making and implementing quality decisions has been applied by the Steering Committee to develop the comprehensive strategy as presented in Table B for ecosystem protection and enhancement. The six steps are:

- Step #1 - Assure leadership and commitment to the decision and the process
- Step #2 - Frame the problem
- Step #3 - Develop a value model and formulate alternatives
- Step #4 - Collect meaningful, reliable data
- Step #5 - Evaluate alternatives and make decisions
- Step #6 - Develop implementation plan.

The Steering Committee has arrived at *Step #5*. Prior to proceeding with *Step #6*, the partner municipalities need to verify the leadership and commitment on the part of each Council to the immediate goal of 'holding the line', and the ultimate goal of 'improving conditions.' To this end, Table C is a matrix that relates the three scenarios (corresponding to three *MDP Levels)* to the set of nine objectives established by the *Brunette Basin Task Group*.

RANGE OF CHOICES FOR ENVIRONMENTAL RISK MANAGEMENT

The report describes *how* to integrate 'environmental risk management' with master drainage planning in order to achieve the stewardship goal of improving conditions over time. Although achieving this goal is separate from 'flood risk management,' the latter does have environmental spin-off benefits (e.g .opportunities for habitat enhancement in conjunction with culvert rehabilitation/replacement).

The primary focus of the report is on identifying achievable elements of a comprehensive and holistic strategy for mitigating *changes in hydrology* and preventing *water pollution*. The final plan will depend on decisions made through the political process. To this end, the GVRD and municipal partners (Burnaby, Coquitlam and Port Moody) essentially have three incremental choices in terms of mitigating environmental risks:

- **Status Quo (Level 2):** Do nothing more than continue current practices.

- **Go Part Way (Level 3):** Protect the Main Stem by diverting flow in the Western Sector, and implementing source controls in conjunction with redevelopment in the Eastern Sector.

- **Go All the Way (Level 4):** Construct regional flow detention and treatment facilities.

The costs to 'go all the way' can be estimated. The benefits are not as easily quantifiable. A reality that may inevitably determine the acceptability of the recommended strategy is that Objective #6 (Minimize Total Costs) in Table C to a large extent offsets the other eight. This underscores the importance of 'willingness to pay' by the community in determining whether the vision as articulated by the Brunette Task Group is achievable.

TABLE D

ACTION PLAN FOR INTEGRATED STORMWATER MANAGEMENT IN THE STONEY CREEK WATERSHED

NO.	ISSUE	RECOMMENDATION
1.	**Framework for Watershed Management**	Adopt-in-principle the framework as presented in Table B for stormwater management and ecosystem protection.
2.	**Component Plan for Environmental Risk Management**	Complete detailed investigations to verify the feasibility of implementing the plan as presented on Figure 7-1 to protect stream corridor ecosystems.
3.	**Component Plan for Flood Risk Management**	Adopt the plan as presented on Figure 7-4 for culvert rehabilitation and/or replacement to systematically resolve problems/concerns related to watercourse erosion, hydraulic adequacy and fish passage.
4.	**EIA (Effective Impervious Area) as a Performance Measure**	Require impervious area reduction measures in redevelopment or new development areas to 'hold the line' at the exiting 23% level for the watershed, and over time reduce the EIA to below 20% to 'improve conditions'.
1A.	**Endorsement by Municipal Councils**	Make presentations to the three municipal Councils (i.e. Burnaby, Coquitlam and Port Moody) to obtain endorsement-in-principle for the four core recommendations above.
1B.	**Public Information Program**	Raise community awareness of (and build support for) the direction in which the inter-municipal partnership for integrated stormwater management is heading.
1C.	**Environmental Agencies**	Reach consensus with the environmental agencies on achievable goals and expectations for 'improving conditions' over time, and for applying EIA as a performance measure.
1D.	**Roles and Responsibilities**	Align the efforts of the GVRD, partner municipalities and municipal departments to achieve the shared vision for watershed and stream corridor management.
2A.	**Habitat Enhancement Program**	Develop a comprehensive program in conjunction with watercourse stabilization and culvert upgrading to systematically improve aquatic habitat conditions in the channel system.
2B.	**Greenway Restoration**	Revegetate riparian corridors and realign trail systems to be 'fish-friendly' and also accommodate human needs.
2C.	**Runoff Quality Control**	Invest in public education, maintenance management programs, and source control regulations; and provide for spill containment at high risk locations.
2D.	**Environmental Health of Stream Corridors**	Implement baseline ambient monitoring of a Benthic Index of Biotic Indicators (B-IBI), as part of an integrated program for monitoring stream corridor health.
3A.	**Watercourse Stabilization Program**	Develop a comprehensive channel maintenance program for systematically addressing localized problems.
3B.	**Culvert Replacement Program for Main Stem**	Undertake pre-design investigations (complete with calibrated hydrologic modelling) to properly analyze the acceptability/feasibility, implementation details and cost of replacing the culvert installations at North Road, Lougheed, Government and the BN/CN right-of-way.
4A.	**Calibrated Computer Model**	Establish an ongoing monitoring and data collection program, undertake a full calibration of the Stoney Creek model with concurrent rainfall and runoff data, and use the model as a monitoring tool to periodically verify the EIA.
4B.	**Criteria for Detention Facility Sizing**	Adopt the criteria as presented in this report for estimating storage volumes and establishing release rates.
4C.	**Sites for Regional Stormwater Detention**	Confirm the feasibility of site development and secure/reserve the three sites identified in this report for possible future construction of regional detention ponds.
4D.	**New Development at Simon Fraser University**	Provide on-site stormwater management measures to reduce post-development impact on runoff, and to meet Level 3 objectives as a minimum.
4E.	**Long-term Effectiveness of Management Strategy**	Establish a GVRD/Intermunicipal protocol agreement for ensuring that the effectiveness of strategy implementation is re-evaluated at 5-year intervals.

RECOMMENDED ACTION PLAN

The set of 19 recommendations presented in Table D provide the basis for an *Action Plan*. The objective is to provide a clear picture of what needs to be done to develop an integrated stormwater management strategy that is achievable, cost-effective, and supported by the public.

There are four 'core' recommendations. Ancillary recommendations that flow from the core recommendations total thirteen, and are numbered to correlate with the first four. Key points to note regarding the ancillary recommendations are highlighted as follows:

- **Decision-Making Process:** The first four are presented separately because they elaborate on Table B and represent next steps in the political process in order to move forward with an Implementation Plan.
- **Technical Investigations:** The next eleven reflect the need for an increasing level of detail to provide direction for the Implementation Plan that would be developed by municipal staffs following endorsement by the municipal Councils of the core recommendations.

Order-of-magnitude capital cost estimates have also been generated to provide a starting point for assessing 'willingness to pay' for stormwater management and ecosystem protection. The total cost to implement a culvert replacement program to address *flood risk management* issues on the Main Stem is in the order of $5½ million (i.e. as part of a *Level 3* program). The additional cost to construct regional diversion and storage facilities for *environmental risk management* would be at least $14½ million (i.e. for Level 4).

INTEGRATION WITH BRUNETTE WATERSHED MANAGEMENT PLAN

The *Brunette Watershed Management Plan* is an evolving document, the final form of which will undoubtedly be significantly influenced by the Stoney Creek process.

The focus of the Stoney Creek process is on determining *how* to achieve the goals and objectives for integrated watershed management as articulated through the Brunette process. To that end, this report has crystallized a drainage planning philosophy, established hydrologic design criteria, identified the elements of a drainage plan, and generated order-of-magnitude cost estimates.

The 'Stoney Creek model' can now be applied to other tributary creeks within the Brunette system. The objective would be to quantify the total financial exposure of each municipality in fully embracing stream stewardship.

The final decision on whether to proceed will be made by the Council of each participating municipality. That decision will be heavily influenced by the cost implications, and the 'willingness to pay' by the public to reduce environmental risks. Hence, the need to verify leadership and commitment to the immediate goal of 'holding the line' (Level 3), and the ultimate goal of 'improving conditions' (Level 4).

DECISION TREE FOR A REGIONAL STORMWATER SYSTEM SERVING THE WESTERN SECTOR OF THE STONEY CREEK WASTERSHED

If there is a political will to move forward incrementally with an *Ecosystem Approach* that integrates stormwater and stream corridor management (Decision #1), then the *Watershed Environmental Goal* is:

Mitigate the frequently occurring storms to hold the line (Level 3) at the time of land development, and over time improve (Level 4) the Stoney Creek stream corridor ecosystem.

▼

1[ST] STEP - GO PART WAY TO AT LEAST ACHIEVE LEVEL 3 (TO MITIGATE NEW DEVELOPMENT AT SFU)

Protect Tributary #3 and the Main Stem of Stoney Creek (above Lougheed Highway) through implementation of source controls at SFU to maintain before-development hydrology. **(Decision #2)**

OR ALTERNATIVELY

If on-site measures cannot be fully realized to protect Tributary #3 and Main Stem above Lougheed Highway, then construct the downstream $1 million Gaglardi Way Phase 1 Diversion (to bypass Tributary #3) **PLUS** the upstream University Drive Interceptor Extension. **(Decision #3)**

AND

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing either the $2.5million Gaglardi Way Phase 2 Diversion and the first phase of the $3 million Western Sector Detention Facility **OR** the $1.0 million Burlington Northern Right-of-Way Detention. **(Decision #4)**

▼

2[ND] STEP - GO ALL THE WAY TO ACHIEVE LEVEL 4 (TO MITIGATE THE ENTIRE WESTERN SECTOR DEVELOPED AREA)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by systematically and progressively achieving EIA reduction targets through a comprehensive and long-term program of source-control measures in all three municipalities. **(Decision #5)**

OR ALTERNATIVELY

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $2.5 million Gaglardi Way Phase 2 Diversion (to bypass the Main Stem) **PLUS** the $3 million Western Sector Detention Facility to serve all development **(Decision #6)**

FIGURE C

IMPLEMENTATION OF THE 50-YEAR VISION FOR ECOSYSTEM PROTECTION

The purpose of this concluding section is to ensure clarity with respect to 'next steps' in the implementation process for an integrated program of stormwater and stream corridor management. To this end, key point to note are highlighted as follows:

1. The strategy for integrated stormwater management comprises component plans for *Flood Risk Management* (to protect property) and *Environmental Risk Management* (to protect ecosystems).

2. Protecting ecosystems requires a long-term commitment and perseverance in implementing watershed measures to achieve EIA reduction targets, and thereby mitigate *changes in hydrology*.

3. Mitigating the *changes in hydrology* would enable slowing the rate of watercourse erosion (to reach an equilibrium condition) so that engineered solutions for cross-section stabilization should not be necessary, with the added benefit that aquatic habitat would be preserved.

4. Thus, the basic choices are to either invest money in the watershed to reduce the EIA (through source-control measures, flow diversion and regional detention, or a combination), or eventually be faced with a capital cost to implement engineered solutions to stabilize stream corridors.

5. In terms of the 6-step process for decision-making, the Steering Committee has reached consensus on a shared vision for stormwater management and ecosystem protection, with the concept of *MDP Levels* providing a framework for moving forward with presentations to elected officials at the regional and municipal levels.

6. Before the staff of the GVRD and partner municipalities can develop an Implementation Plan, however, it will be necessary to verify leadership and commitment on the part of elected officials.

7. Figure C complements Table B and provides supplementary detail with respect to the series of decisions that need to be made by elected officials and SFU in incrementally determining whether to invest $6½ million for full regional detention in the *Western Sector Drainage Area* to improve conditions in the Stoney Creek ecosystem.

8. Figure D is a parallel decision tree for the $8 million investment that could be potentially needed to provide full regional detention in the *Eastern Sector Drainage Area.*

In conclusion, integrated stormwater management (by definition) considers all the rainfall events that comprise the annual runoff hydrograph, and comprises two distinct components: the *hydrotechnical component* that is concerned with the dramatic flood impacts associated with the infrequently occurring large storms; and the *environmental (or enhanced hydrotechnical component)* that addresses the insidious impacts of the frequently occurring small storms on stream corridor ecology.

DECISION TREE FOR A REGIONAL STORMWATER SYSTEM SERVING THE EASTERN SECTOR OF THE STONEY CREEK WASTERSHED

If there is a political will to move forward incrementally with an *Ecosystem Approach* that integrates stormwater and stream corridor management (Decision #1), then the *Watershed Environmental Goal* is:

Mitigate the frequently occurring storms to hold the line (Level 3) at the time of land redevelopment, and over time improve (Level 4) the Stoney Creek stream corridor ecosystem.

▼

1ST STEP - GO PART WAY TO AT LEAST ACHIEVE LEVEL 3
(TO MITIGATE RE-DEVELOPMENT)

Protect the Main Stem of Stoney Creek (all the way to the Brunette confluence) through implementation of source controls in conjunction with land redevelopment to maintain the before-redevelopment hydrology. **(Decision #2)**

▼

2ND STEP - GO ALL THE WAY TO ACHIEVE LEVEL 4
(TO MITIGATE THE ENTIRE EASTERN SECTOR DEVELOPED AREA)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by systematically and progressively achieving EIA reduction targets for the entire Eastern Sector through a comprehensive and long-term program of source-control measures supported by bylaws and regulations in all three partner municipalities. **(Decision #3)**

OR ALTERNATIVELY, AND
CONSIDERING ONLY THE COQUITLAM/PORT MOODY TRIBUTARY AREA

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $4 million Tri-Municipalities Detention Facility near the confluence of Tributary #3 and the Main Stem. **(Decision #4)**

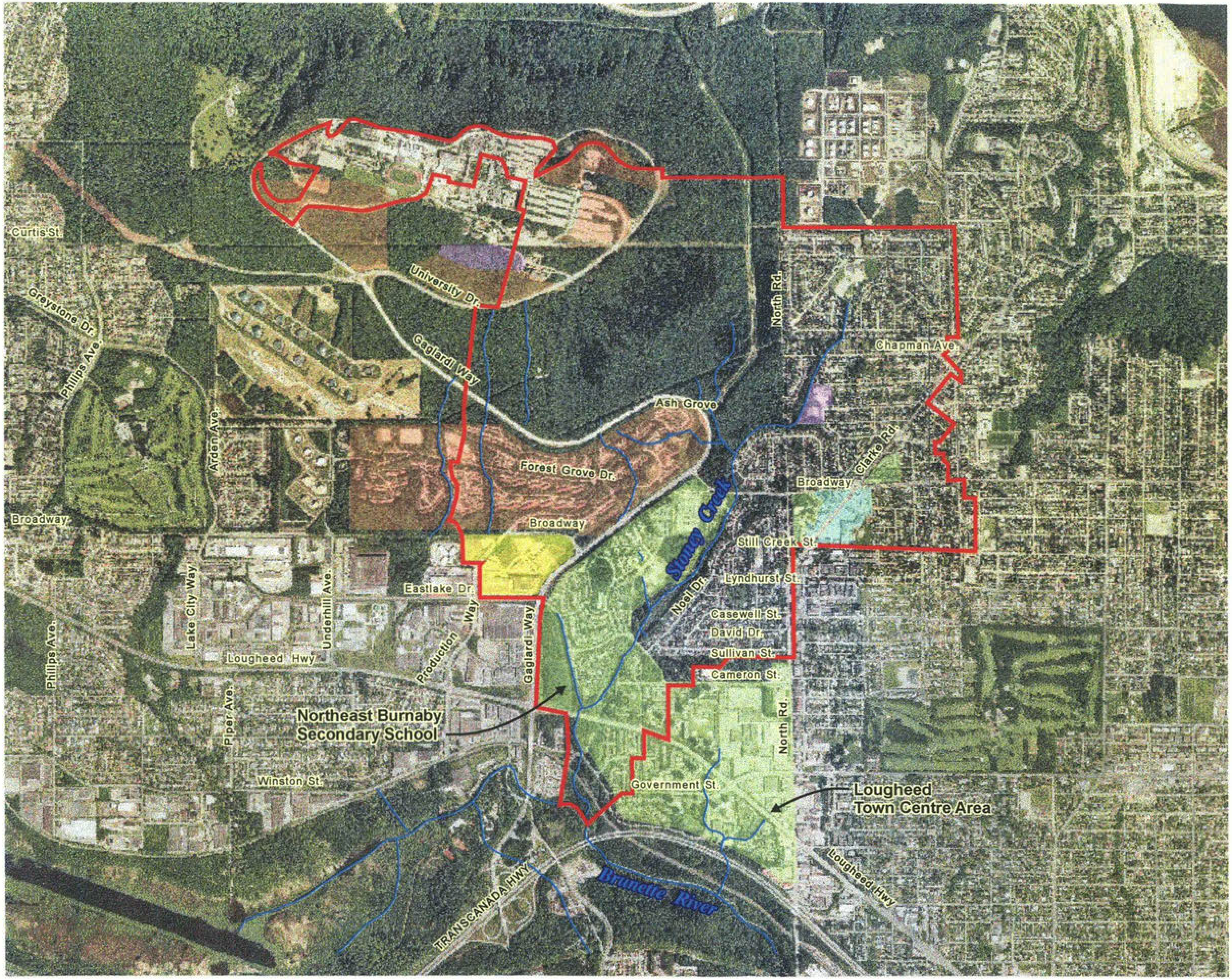
OR ALTERNATIVELY, AND
CONSIDERING ONLY THE LOUGHEED TOWN CENTRE AREA
(north of Cameron Street)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $2 million Noel Drive Interceptor Sewer (to intercept existing outfalls) **PLUS** the $2 million Loughheed Town Centre Area Detention Facility (south of the Lougheed Highway). **(Decision #5)**

FIGURE D

CHAPTER 1

BACKGROUND



LEGEND

- Industrial
- Agriculture
- Commercial
- Institutional (School, Etc.)
- Single Family Residential
- Multi Family Residential
- High Density Apartment / Commercial

NOTES:

Future land use approximated based on Official Community Plans (OCPs) provided by the cities of Coquitlam, Burnaby, and Port moody.

KWL-CH2M
CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

500 0 500
Scale In Metres

PROJECT No.	DATE:
1045-002	SEPT. 25, 1998

FUTURE CHANGES IN LAND USE

FIGURE 1-1

1045-002 \ FIG1-1

1. BACKGROUND

1.1 Overview of Stoney Creek Watershed

Description of Study Area

The purpose of this study is to develop a stormwater management strategy for Stoney Creek, a tributary of the Brunette River. Figure 1-1 shows the extent of the Stoney Creek drainage area. The study involves an inter-municipal partnership because the tributary area encompasses parts of three cities, namely: Burnaby, Coquitlam and Port Moody. The study area also includes Simon Fraser University SFU).

Stoney Creek comprises a main stem plus three tributary channels that originate on Burnaby Mountain to the west. The characteristics of the watershed are summarized as follows in terms of two sub-watershed management units:

- **Eastern Sector:** This refers to the area on the east side of the Main Stem. It is completely urbanized with well-established neighbourhoods and commercial zones. More than half of this sub-area lies within Coquitlam and Port Moody. The Lougheed Town Centre abuts the southern boundary.
- **Western Sector:** This refers to the area on the west side of the Main Stem. Roughly half of this sub-area is urbanized with a mix of single family and high density residential neighbourhoods, as well as an industrial zone. The other half is the newly created Burnaby Mountain Park.

Figure 1-1 also highlights anticipated future changes in land use.

Identification of Future Development and Redevelopment Areas

Creation of Burnaby Mountain Park has resulted in preservation of forested land, and minimized the proportion of land that is available for new development. In fact, the anticipated future development is limited to two projects:

- **Simon Fraser University:** Within the next couple of years, SFU will be proceeding with a multi-year program for mainly multi-family residential development within the Ring Road (i.e. University Drive).
- **Northeast Burnaby Secondary School:** Construction is presently underway for a new school on the triangular piece of property bounded by Gaglardi Way on the west and Lougheed Highway on the south.

It is likely that the older housing stock in existing residential areas will eventually be replaced with larger homes that will have less green space. In addition, Figure 1-1 shows proposed future densification in and around the Lougheed Town Centre area.

TABLE 1-1

COMPONENTS OF THE ENGINEERING WORK PROGRAM FOR DEVELOPMENT OF AN INTEGRATED STORMWATER MANAGEMENT STRATEGY

PART	DESCRIPTION	SCOPE OF COMPONENT
A	Storm Runoff Control	The focus is on mitigating flood and erosion damage resulting from peak flows during major storm/runoff events (i.e., Q_{10} and Q_{100})
B	Aquatic Habitat Protection and Enhancement Evaluation	This involves development of a strategy for ensuring the *environmental health* of major streamside resources, including both riparian and in-stream habitat.
C	Runoff Quality Control	The focus is on water quality for aquatic life, with particular emphasis on developing guidelines for the preservation of water quality in Stoney Creek for fish habitat.
D	Consensus-Building	This involves working with the Steering Committee to develop a shared vision regarding the goals and objectives for watershed and stream corridor management.

1.2 Starting Point for Engineering Work Program

Identification of Driving Forces

The need for the *Stoney Creek Stormwater Management Strategy* has been triggered by the following developments:

- **Liquid Waste Management Plan (LWMP):** In November 1994, the Greater Vancouver Regional District (GVRD) embraced regional stormwater planning as part of the *Stage 2 LWMP*. Inclusion of stormwater quality was triggered by a policy stateement from the Ministry of Environment in February 1994. The essence of the statement was that local governments should identify how they will reduce the contaminants contained in stormwater.

- **Community Expectations**: Read together, the *Simon Fraser University Official Community Plan* and the *Lougheed Town Centre Plan* present a vision of the future for the Stoney Creek watershed, and provide a benchmark for referencing the goals and objectives of the master drainage and environmental planning processes.

- **Legislative Initiatives**: A key piece of legislation from a local government perspective is the recently proclaimed *Bill 26* because it complements the *Fish Protection Act*, amends the *Municipal Act*, and provides local government with the tools to protect the natural environment, its ecosystems and biological diversity.

Given the foregoing frame-of-reference, the study is described as a "pilot program within a pilot program" because of the opportunity it provides to advance *Integrated Master Planning and Stormwater Management* within the Greater Vancouver region.

Overview of Pilot Program Concept

The Stoney Creek drainage area is an important sub-catchment of the Brunette River Basin because of its fisheries value. Furthermore, the GVRD has responsibility for management and maintenance of the Brunette-Stoney channel system. This has enabled the GVRD to establish the *Brunette Basin Task Group*. The goal is to develop a comprehensive strategy and multi-stakeholder process for watershed management.

The intention is that the "Stoney Creek model" would then be applied to other sub-catchments within the Brunette system. Similarly, the "Brunette model" could be applied to other urban drainage systems within the region.

Introduction to Study Components

Strategy development involves integration of four components as identified in Table 1-1. The components are linked, as the output from one becomes input to the next.

1.3 Defining a Shared Vision for Community Livability

The challenge is to develop an *Integrated Stormwater Management Strategy* that is practical, cost-effective, and achievable. The following hierarchy provides a benchmark for referencing the goals and objectives of the master drainage and environmental planning processes.

Level	Description of Initiative	Purpose
1	Provincial Legislation	Provide local government with enabling tools
2	Official Community Plan	Define community goals and livability objectives
3	Brunette River Watershed Management Plan	Establish priorities for natural resource sustainability
4	Stoney Creek Stormwater Management Plan	Protect property and ecosystems

Ensuring that the strategy is realistic and supported by the community requires an understanding of what may be achievable in terms of environmental protection.

1.4 Framework for Integrated Master Planning

The fundamental question that must be addressed by the master drainage planning process is this: *How can the ecological values of stream corridors and receiving waters be protected and enhanced by a Master Drainage Plan, while at the same time the plan is facilitating land development and/or redevelopment?* Given this starting point, the following diagram conceptualizes the basic components of an ecosystem-based approach to stormwater management:

To select an appropriate management strategy, it is first necessary to identify the resources being protected, the threats to those resources, and the alternative management strategies.

1.5 Evolution of Drainage Planning Philosophy

An Historical Perspective

In the mid-1970's, a major breakthrough in contemporary drainage planning was the realization that upstream activities have downstream impacts. Concerns over watercourse stability and capacity eventually provided the driving force behind the requirement for stormwater detention facilities in new subdivisions, the primary function of which was to maintain peak runoff rates at pre-development levels for a specified return period.

This represented a departure from past practice, as the historical approach to urban drainage design was simply to collect stormwater runoff in a system of buried pipes and removed it from the drainage basin as rapidly as possible.

By the early 1980s, a watershed management philosophy was becoming an integral part of master drainage planning in British Columbia. This was an outcome of the realization in the 1970s that drainage facilities do, in fact, form part of a continuous system.

Watershed management typically meant mitigating the downstream consequences of changes in upstream land use. In short, the primary focus was on hydrotechnical solutions such as watercourse stabilization, with the approach to problem-solving being generally reactive rather than proactive.

Two decades after the initial breakthrough in drainage planning, society's concern for the environment has resulted in another turning point in the evolution of drainage planning philosophy. The goal of the master drainage planning process in the late 1990s is to develop an *Integrated Stormwater Management Strategy* for creek systems that is hydrotechnically sound, environmentally sensitive, and fiscally responsible.

Identification of Levels of Master Planning

Table 1-2 identifies six levels of master drainage planning that reflect the evolution of a guiding philosophy over the decades. Each level becomes progressively more sophisticated, with the defining phrase for each decade highlighted as follows:

- **1960s Approach:** Pipe and Remove
- **1970s Approach:** Detain Peak Flows
- **1980s Approach:** Reactive Mitigation
- **1990s Approach:** Proactive Management

Table 1-2 also provides a conceptual framework for implementing stream stewardship. Strategic objectives are defined, and management practices for achieving those objectives are identified. Emphasis is placed on public education and community involvement.

TABLE 1-2

SELECTION OF GUIDING PHILOSOPHY FOR MASTER DRAINAGE PLANNING:
Conceptual Framework for Implementing Stream Stewardship in Either an Existing Urbanized or Developing Watershed

Level	Guiding Philosophy for MDP (Master Drainage Plan)	Strategic Objectives	Identification of Management Practices		Impact on Aquatic Habitat
			Hydrotechnical	Environmental/Social	
1	**Protect Property** *(1960s Approach)* Provide basic drainage servicing for peak flow conveyance and discharge to nearest receiving water.	• Construct efficient drainage network to protect property and minimize inconvenience. • Focus on peak flows and drainage risks. • Analyse major/minor flow paths.	• Standard storm sewer design • Standard culvert design		• Increased peak flows for all events L • Lower base flows L • Greater erosion and sediment loads L • Pollution L • Water temperature rises L
2	**Mitigate Major Development Impacts** *(1970s and 1980s Approach)* Provide detention storage for major events to maintain peak discharge rates at pre-development levels.	*All of the above, plus:* • Protect creek corridors from development. • Attenuate peak flows for major events only.	*All of the above, plus:* • Leave strips • Project detention ponds • Community detention ponds • Amour eroding creek sections	• Minimal public information	• Insidious erosion impacts during frequent events L • Water temperature may rise further L • Loss of riparian habitat in armoured areas.L • Damage from infrequent events reduced to J natural levels • Possible reduction in peak flows for frequent events J
3	**Preserve Aquatic Habitat** *(1990s Approach)* Implement Best Management Practices (BMPs) that mitigate the effects of redevelopment by at least maintaining existing conditions in stream corridors so that there will be no further loss of biodiversity and abundance.	*All of the above, plus:* • Maintain the effective impervious area at pre-redevelopment levels. • Improve stormwater quality. • Consider protective measures for areas of high natural resource value.	*All of the above, plus:* • Source infiltration techniques • Source attenuation techniques • First level source quality controls • Creek bypasses • Retrofit existing ponds for frequent event attenuation and/or settling • Selected practices from the next two levels where opportunities exist.	*All of the above, plus:* • Selected practices from the next two levels where opportunities exist. • Public education	• Prevents worsening of creek conditions due to redevelopment. J • Protects and enhances habitat in selected areas of the creek system (more natural flow, temperature, pollutant, and sediment regimes). J
4	**Improve Aquatic Habitat** Implement BMPs that compensate for the effects of redevelopment by improving conditions in stream corridors so that biodiversity and abundance will be enhanced.	*All of the above, plus:* • Reduce the effective impervious area from pre-redevelopment levels. • Attenuate peak flows for frequent events. • Provide primary treatment of stormwater.	*All of the above, plus:* • Community infiltration facilities • Primary treatment (settling ponds) • Modified/additional detention ponds • Baseflow augmentation	*All of the above, plus:* • Limit human activity in some areas • Public volunteer enhancements (stream surveys, trash removal, placement of habitat structure, revegetation) • Reduce existing impervious surfaces	• More natural flow, temperature, pollutant, and sediment regimes. J • Supports hatchery fish stock an d possibly some wild population. J
5	**Restore Aquatic Habitat** Implement BMPs in conjunction with restoration of habitat in stream corridors so that biodiversity and abundance will be increased.	*All of the above, plus:* • Severely restrict the effective impervious area after redevelopment. • Provide enhanced treatment of stormwater.	*All of the above, plus:* • Secondary and tertiary treatment (biological & filtration) • Real-time stormwater flow control • Combined sewers • Pervious pavement	*All of the above, plus:* • Severely restrict human activity in creek corridors • Native vegetation buffers along all water bodies • Strict source controls - banning phosphorous detergents, eliminating copper and zinc in automotive products [brake linings, tires, motor oil], restricting fertilizer types and application	• Reasonably natural flow, temperature, pollutant, and sediment regimes. J • Supports the full life cycle of some limited wild fish stocks. J
6	**Restore Entire Watershed** *(Create Utopia)* Implement BMPs and return stream corridors to a pristine condition so that biodiversity and abundance will be fully restored.	*All of the above, plus:* • Reduce the effective impervious area to zero after redevelopment. • Eliminate stormwater pollution.	*All of the above, plus:* • Technologies not yet developed.		• Supports the full life cycle of all fish stocks that naturally occurred prior to initial settlement and development. J

1.6 Approach to Information Presentation

Our approach to information presentation is to clearly define the issues, and then progressively zoom into successive layers of detail. Our approach is also captured by this axiom: "Say what you are going to say. Say it. And then say what you said." The objective is to develop a theme, with each chapter building on the frame-of-reference provided by the preceding chapters.

1.7 Steering Committee and Project Team

The study was carried out by a 7-person consulting team as listed below. The *Leadership Team* comprised Kim Stephens and Bill Derry, with Bill taking the lead role in developing the consensus-building component of the work program. Kim was principal author for the report, with Bill Derry contributing Chapter 3.

Ron Kistritz was responsible for the aquatic assessment and water quality monitoring programs, while Chris Johnston was responsible for the hydrotechnical program (i.e. watercourse investigations plus computer modelling). Chris also worked closely with Ron in developing and implementing the water quality monitoring program. Ron contributed Chapters 5 and most of Chapter 6.

Name	Organization or Role
Steering Committee	
Lambert Chu, Chair	Engineering Department, City of Burnaby
Susan Haid	Planning Department, City of Burnaby
Kevin Connery	Planning Department, City of Burnaby
David Palidwor	Parks department, City of Coquitlam
Julie Pavey	Environmental Services, City of Port Moody
Ed von Euw	Greater Vancouver Regional District
Caroline Berka	Greater Vancouver Regional District
Ken Hall	Westwater Centre, University of B.C.
Bob Brown	Simon Fraser University
Bob Gunn	B.C. Institute of Technology
Jennifer Atchison	Stoney Creek Environmental Committee
KWL-CH2M Staff	
Kim A. Stephens	Project Manager
Bill Derry	Senior Consultant
Chris Johnston	Project Engineer
Andrea Morgan	Water Resources Engineer
Andrew Boyland	Water Resources Engineer
John Delver	Water Resources Technologist
Specialist Consultant	
Ron Kistritz	Aquatic Ecology and Water quality

CHAPTER 2

INTEGRATED MASTER PLANNING AND STORMWATER MANAGEMENT

A Proven Model For Stream Stewardship

Figure 2-1 An environmental approach to Master Drainage Planning in the 1990's

1045-0021FIG2-1.CDR

2. INTEGRATED MASTER PLANNING AND STORMWATER MANAGEMENT

2.1 What is a Master Drainage Plan

A *Master Drainage Plan (MDP)* is an integral component of a municipality's land development and growth management strategy because upstream activities have downstream consequences. Hence, an MDP has four objectives:

1. **Route urban runoff from uplands areas through lowlands areas.**
2. **Alleviate existing and/or potential drainage, erosion and flooding concerns**
3. **Protect major streamside resources, including riparian and aquatic habitat**
4. **Remediate existing and/or potential water quality problems**

The goal of the master planning process in the 1990s is to develop an *Integrated Stormwater Management Strategy* that protects property while sustaining natural systems and accommodating growth. Figure 2-1 identifies the four building blocks that address the spectrum of stormwater quantity and quality issues.

2.2 What Is An Integrated Stormwater Management Strategy

An *Integrated Stormwater Management Strategy* considers all the rainfall events that comprise the annual runoff hydrograph, and comprises two distinct components:

Component	Management Objective	Hydrotechnical Focus	Type of Impact
Hydrotechnical	Protect Property	Infrequently Occurring Large Storms	Dramatic (flood and erosion damage resulting from peak flows)
Environmental (Enhanced Hydrotechnical)	Protect Ecosystems	Frequently Occurring Small Storms	Insidious (water quality deterioration, watercourse erosion and sedimentation resulting from the increased number of runoff events per year.)

Understanding the relationship between watershed impervious percentage, watercourse stability, and aquatic biodiversity is fundamental to developing an integrated strategy that is practical, cost-effective and supported by the community.

Figure 2-2 illustrates the progressive *changes in hydrology* that result from an increasing percentage of impervious area. Resolving the hydrotechnical issues related to the *frequently occurring small storms* would have spinoff environmental benefits in terms of protecting/ preserving aquatic habitat.

Factors Limiting the Ecological Values of Urban Streams and Waterways

Changes in Hydrology

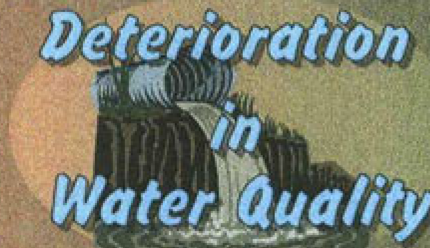
... due to increasing impervious surface area, and densification of the road network.

Disturbance to the Riparian Corridor

... due to land clearing and removal of natural vegetation.

Disturbances to Fish Habitat

... due to pool/riffle ratios, removal of large organic debris, bank hardening, and erosion /sedimentation processes.



Deterioration in Water Quality

... due to pollutant washoff from high density land uses, waste discharge from commercial operations, and accidental spills of industrial products.

KWL–CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

1045-0021FIG2-4.CDR

Figure 2-

2.3 Correlation of Impervious area with Stream Corridor Health

Figure 2-3 builds on Figure 2-2, and conceptualizes the consequences for the environmental health of a stream corridor. Approximate threshold levels of impervious area are identified as follows:

- **Initial Impact:** With as little as 8% to 12% impervious surface in a watershed, changes in hydrology occur that result in irreversible impacts to fish habitat.

- **Urban Impact**: When total watershed imperviousness is 30% to 35%, the changes in hydrology and physical habitat are usually so significant that it may be unable to sustain abundant self-supporting populations of cold water fish.

Although local environmental conditions such as riparian habitat protection or a major investment in BMPs may moderate these impacts, no existing technologies can reverse the pattern. Figure 2-4 complements Figure 2-3 by ranking the four major factors limiting the environmental values of urban streams.

By the time pollutant loading is a significant factor in terms of fish survivability, for example, the hydrological changes resulting from land use densification would have already flushed out the habitat.

2.4 Selection of a Guiding Philosophy

Bringing together the hydrotechnical and environmental components of an "integrated strategy" requires an holistic approach that addresses these three defining questions.

- **Developing an Integrated Master Plan:** How can the ecological values of stream corridors and receiving waters be protected and enhanced by a Master Drainage Plan, while at the same time the plan is facilitating land development and/or redevelopment?

- **Achieving Community Objectives:** How can a municipality move forward with a Drainage Capital Plan that is affordable and cost-effective in solving erosion and flooding problems, while meeting the *Official Community Plan* objectives for a sustainable environment?

- **Funding an Integrated Master Plan:** How does a municipality optimize what is acceptable in terms of community willingness to pay versus environmental risks and consequences, and then build understanding and support among the public for a funding plan?

Figure 2-5 is an important *decision-making tool* that is science-based. The concept of *MDP Levels* as shown in the figure, facilitates the process of defining a guiding philosophy, and assessing whether hydrotechnical solutions are also environmentally and politically acceptable.

TABLE 2-1

FRAMEWORK FOR DEVELOPMENT OF THE ENVIRONMENTAL COMPONENT OF AN INTEGRATED STORMWATER MANAGEMENT STRATEGY

ACTION ITEM	IDENTIFICATION OF STRATEGIC INITIATIVE	SYNOPSIS OF ASSOCIATED STRATEGIC OBJECTIVE
1	Adopt an Ecosystem Approach to Drainage Planning	Bring together the environmental and technological paths in addressing the spectrum of stormwater quantity and environmental quality issues through the master drainage planning process, and select environment goals that are achievable.
2	Protect Environmental Resource Values	Develop a practical 'aquatic habitat protection strategy' that reflects a full and proper understanding of sustainability and biodiversity in an urban environment, and that attains a fair and equitable balance between fish protection and other community goals.
3.	Integrate Stormwater Management with Land Use Planning	Define roles and responsibilities so that City departments can be proactive in aligning their efforts to facilitate land development while protecting property and sustaining ecosystems; and adopt a watershed-based approach to sustainable development that considers the relative placement of different land uses and the beneficial impact of *alternative design standards* on the hydrologic regime.
4	Construct Wet Ponds for Stormwater Detention and Treatment	Assess the feasibility and effectiveness of constructing *wet ponds* at strategic locations for peak flow atenuation and/or pollutant removal. Or alternatively, consider increased over-bank conveyance capacity and/or diversions.
5	Implement Best Management Practices (BMPs)	Identify opportunities to apply other BMPs that are appropriate Stoney Creek conditions, that can be applied at source, and that mitigate the more subtle changes in hydrology that would otherwise result from increasingly higher percentages of impervious ground cover.
6	Protect Stream Corridors in the Urban Areas	Assess the cost-benefit implications of restoring ecological functions in greenways, with the objective of preserving the environment and natural beauty of Stoney Creek while achieving a balance with other demands and goals.

2.5 Identification of Master Plan Deliverables

The ultimate deliverable would be an *Integrated Stormwater and Natural Resource Management Plan* that would comprise the following three products:

DELIVERABLE	SCOPE OF DELIVERABLE
A complete inventory of the physical system	• streams and rivers • wetlands, ponds and lakes • infiltration areas and aquifers • flooding and erosion problem areas • water quality problems
A plan to protect the resources, resolve identified problems, and accommodate growth	• 10-year plan for drainage system improvements • long-term plan for drainage system improvements • description of regulations needed • cost estimates
A management program	• administration • monitoring • education • maintenance activities, standards and schedules • financing sources

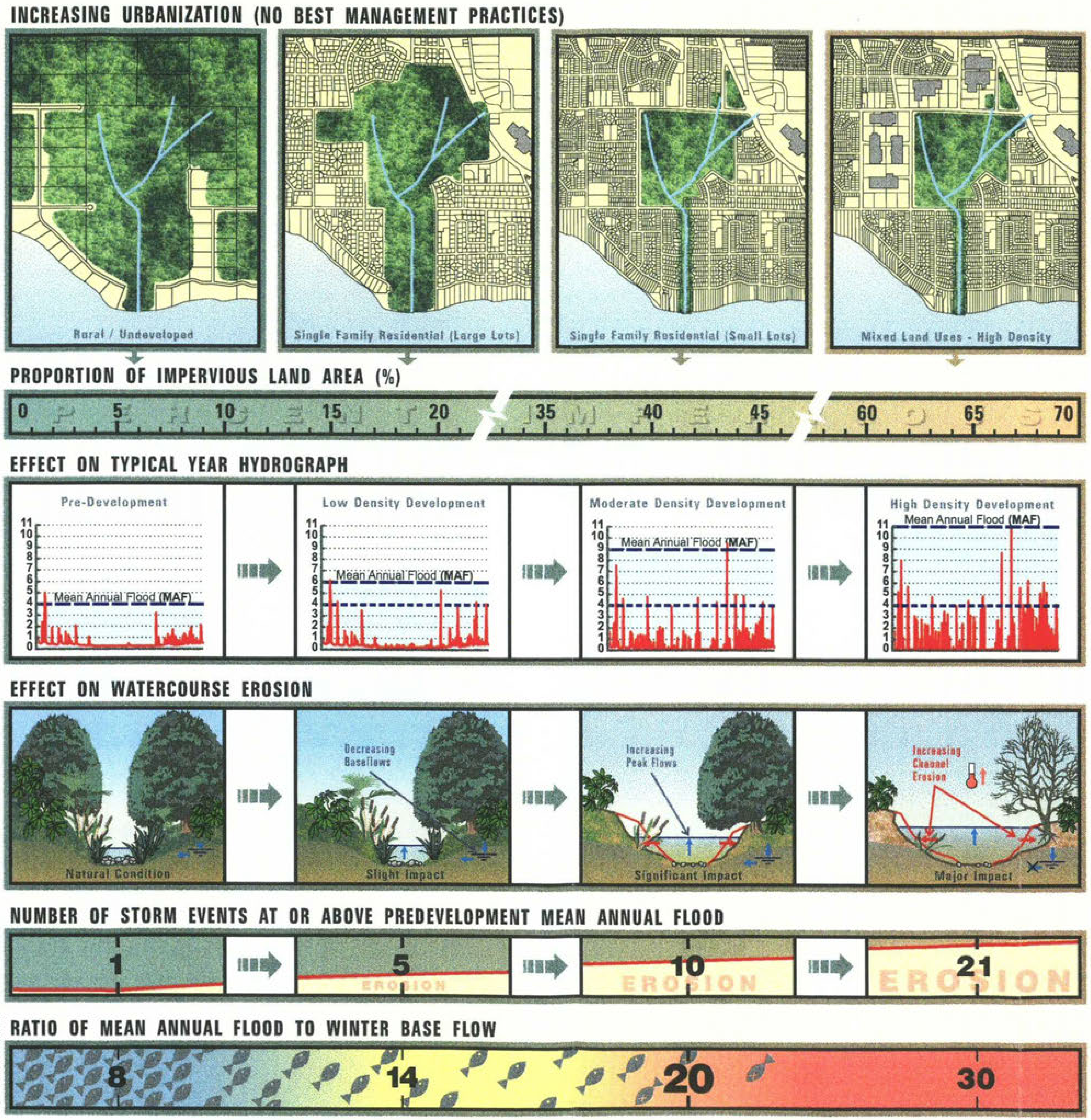
These products should be developed in a partnering process with the community that will engender public support for the integrated master plan. Development and implementation of a customized plan to suit the concerns, needs, means, and priorities of either the regional district or a municipality would require a major commitment to a systematic consensus-building process.

2.6 Development of an Integrated Master Plan

A set of six *Strategic Objectives* that provide a framework for development of the 'environmental component' of an integrated stormwater management plan is presented in Table 2-1.

Figure 2-3 illustrates the environmental consequences as a result of not addressing the *frequently occurring small storms*. The increased frequency-of-occurrence of threshold rates of runoff exacerbate erosion and sedimentation processes that damage aquatic/riparian habitat.

Through a *Level 3 MDP* (as defined by Table 1-1 and Figure 2-5), the goal would be to implement BMPs that mitigate the effects of land use densification so that the rate of stream channel change is stabilized, and to minimize further loss of biodiversity and abundance (i.e. 'hold the line').



IMPACT OF CHANGES IN HYDROLOGY ON WATERCOURSE EROSION AND BASE FLOW RELATIONSHIPS

(WITHOUT BEST MANAGEMENT PRACTICES)

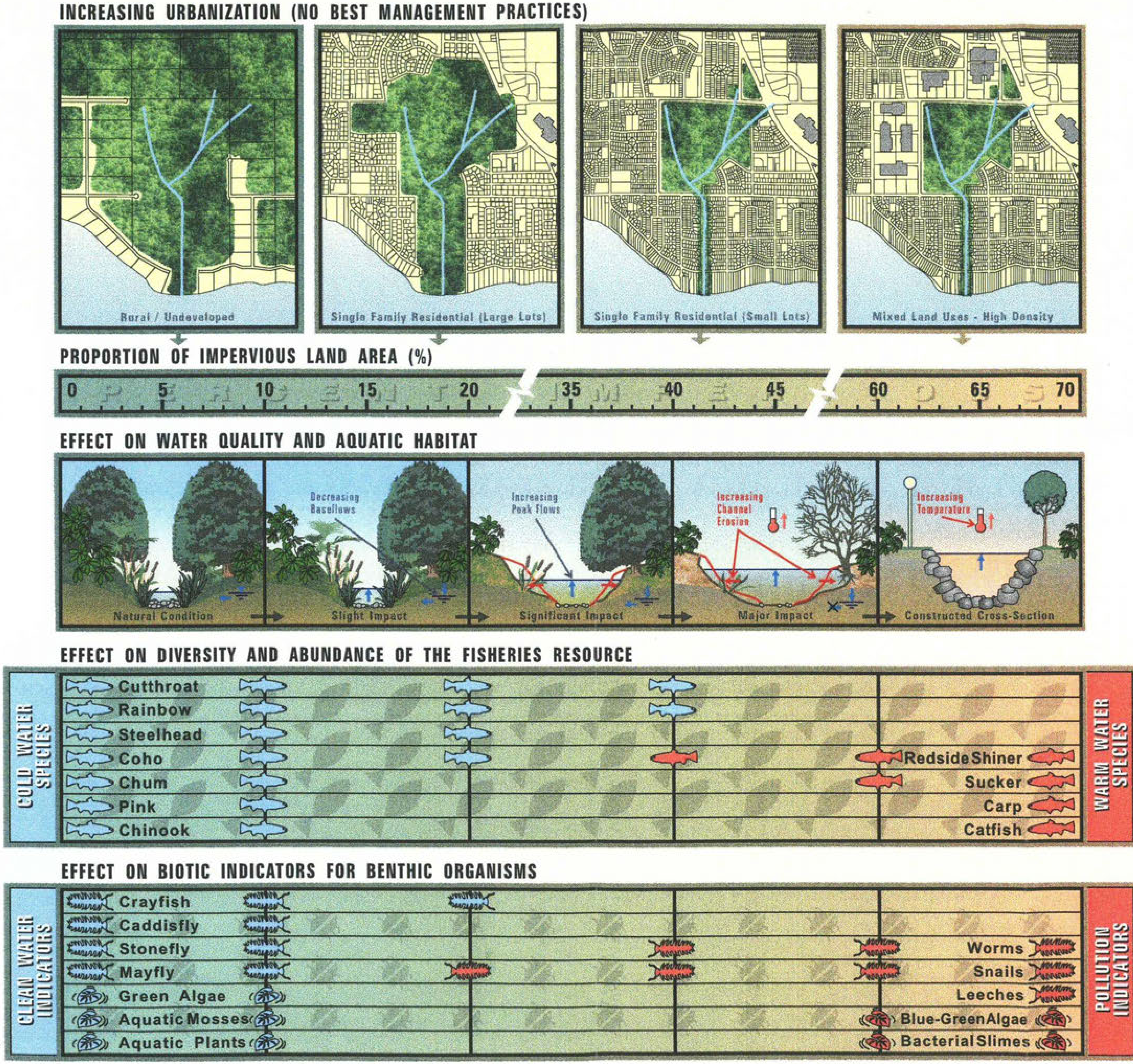
This figure demonstrates the impact of increasing impervious area on the number of erosion-causing events, and increased peak flow impacts on channel stability. Although it is based on a calibrated model and continuous simulation of rainfall-runoff response in the North Shore region of Greater Vancouver, the figure is intended for conceptual purposes only.

FIGURE 2-2

KWL CH2M
CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

IMPACT OF INCREASING URBANIZATION ON STREAM CORRIDOR ECOLOGY

(WITHOUT BEST MANAGEMENT PRACTICES)



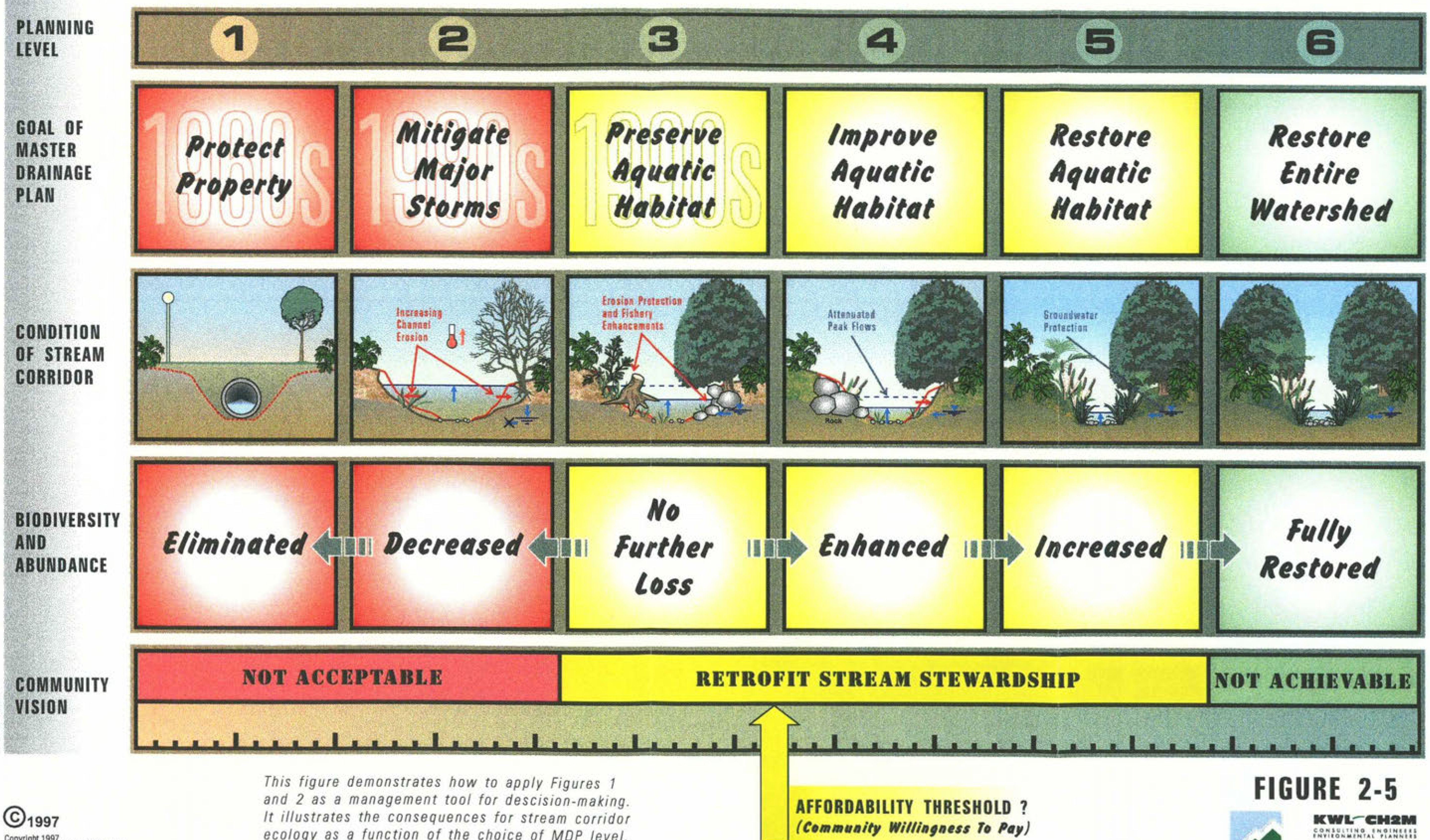
This figure demonstrates the impact of increasing impervious area on species diversity. Although it is based on research findings for lowland streams in the Puget Sound region of Washington State, the figure is intended for conceptual purposes only.

FIGURE 2-3

KWL CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

ALTERNATIVE VISIONS FOR THE LONG-TERM ENVIRONMENTAL HEALTH OF STREAM CORRIDORS

Conceptual Framework For Selection Of Master Drainage Plan (MDP) Level



This figure demonstrates how to apply Figures 1 and 2 as a management tool for descision-making. It illustrates the consequences for stream corridor ecology as a function of the choice of MDP level.

FIGURE 2-5

KWL–CH2M CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

1045-002/FIG2-5.CDR

2.7 Land Use Densification and Peak Runoff Rates

Application of the Four Limiting Factors

Understanding the four limiting factors as illustrated on Figure 2-4 is key to developing guiding principles for an integrated approach to stormwater and stream corridor management. Looking ahead to Chapters 3 and 7, these four factors provide the 'roadmap' for crystallizing achievable goals and defining management objectives, especially as they relate to mitigation of *changes in hydrology*. To this end, the distinction between the two types of storm and runoff conditions needs to be emphasized:

- **Frequently Occurring Small Storms:** Under natural forested conditions, there is no runoff from small storms. Once land is urbanized, however, runoff results.
- **Infrequently Occurring Large Storms:** Flood flows usually occur at the end of a prolonged wet-weather period when the pervious ground is fully saturated and contributing runoff.

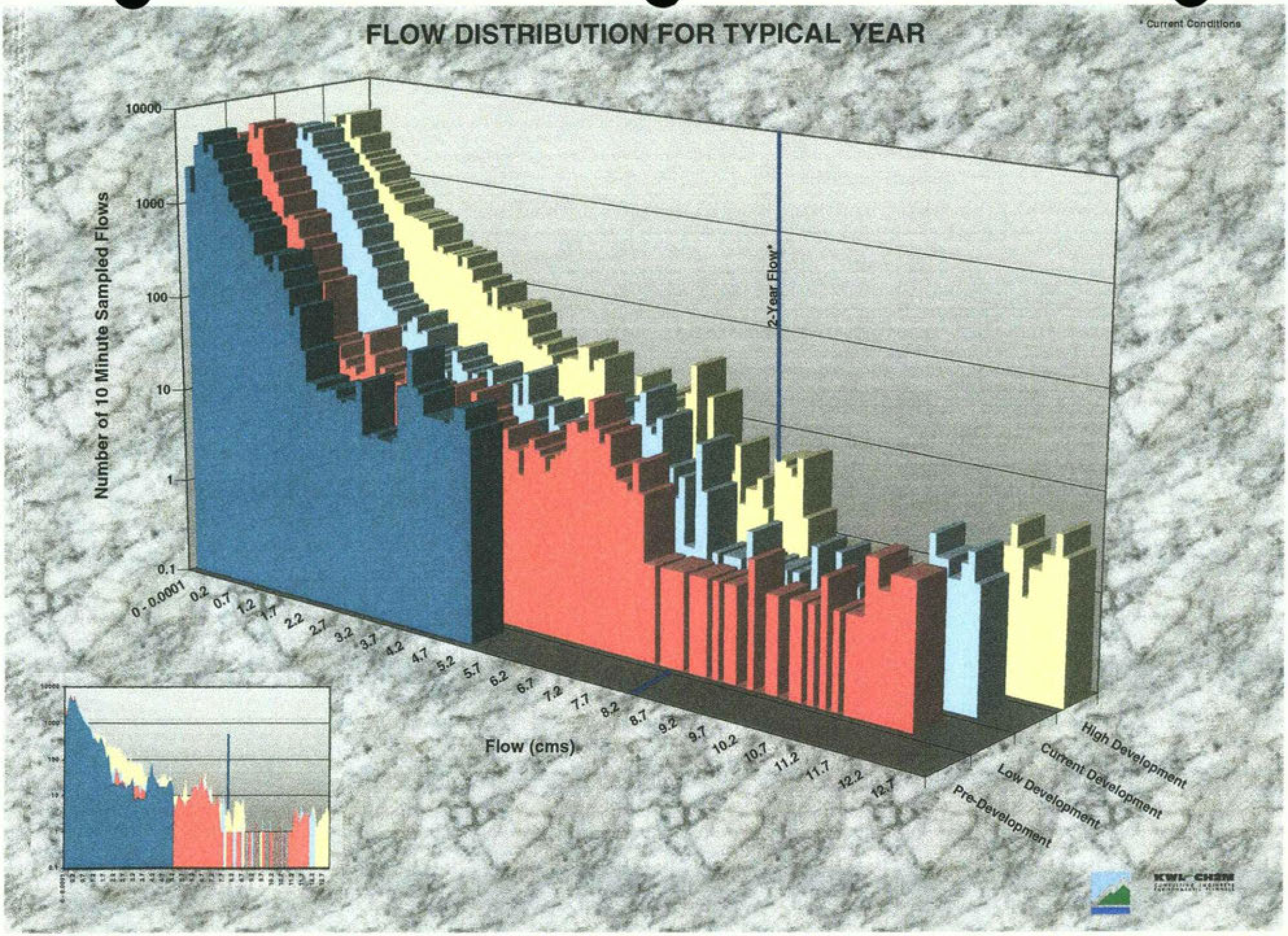
Roughly 95% of the annual rainfall events in the Greater Vancouver region have less than 2.5mm of rainfall. Prior to land development, this amount is insufficient to produce runoff.

Impact of Land Re-Development on Peak Runoff Rates and Occurrence

Based on recent hydrometric data collection and model calibration initiatives in the Greater Vancouver region, noteworthy findings are highlighted as follows:

- **Initial Impact:** Runoff response to rainfall is noticeable once a forested area is first cleared and ditched for residential development.
- **Incremental Impact:** For an already urbanized area that is undergoing densification of land use, the incremental increases in peak runoff rates for the major storms are marginal (i.e. 5% to 10%).
- **Frequency of Occurrence:** The main impact of densification is the increased number of minor runoff events per year that are likely to exceed a 'threshold velocity' for watercourse erosion.

Figure 2-6 illustrates the 'changes in hydrology' for a *typical year* as a result of land use densification. This shows the flow distribution in two dimensions in order to emphasize the increased frequency-of-occurrence of runoff during the smaller storms. By mitigating the smaller storms, the goal of 'environmental risk management' is ecosystem protection. Providing protection against the big storms is the goal of 'flood risk management.'



FLOW DISTRIBUTION FOR TYPICAL YEAR
* Current Conditions
Number of 10 Minute Sampled Flows
10000
1000
100
10
1
0.1
2-Year Flow*
0 - 0.0001
0.2
0.7
1.2
1.7
2.2
2.7
3.2
3.7
4.2
4.7
5.2
5.7
6.2
6.7
7.2
7.7
8.2
8.7
9.2
9.7
10.2
10.7
11.2
11.7
12.2
12.7
Flow (cms)
High Development
Current Development
Low Development
Pre-Development
KWL CH2M

FIGURE 2-6

2.8 Assessment of Winter versus Summer Conditions

Overview of Climate Conditions in British Columbia

Under southwest British Columbia climate conditions, rainfall patterns in summer are different from those in winter. Significant summer storms are characterized by high intensity, short duration rainfall. Winter storms, on the other hand, are characterized by lower intensities over much longer durations. The breakpoint on IDF (Intensity-Duration-Frequency) curves between summer and winter storms is at approximately 60 minutes. For durations less than this critical time, summer storms govern the IDF curve; whereas winter storms given for times greater than 60 minutes.

Application of Rainfall Distributions for Streamflow Estimation

Winter storms typically govern the peak flow rates in major creek channels that have long times of concentration, whereas summer storms govern for small storm sewered areas that have short times of concentration.

This finding has significant implications in terms of understanding the results of rainfall-runoff data collection and model calibration programs. The over-riding consideration is the relationship between antecedent conditions and runoff contribution from impervious and pervious areas.

Impact of Antecedent Conditions on Peak Runoff Rates

History shows that a prolonged Fall/Winter wet-weather period typically results in the ground being fully saturated by the time a major storm arrives. As a consequence, runoff should be maximized.

Under summer conditions, on the other hand, pervious ground will normally have considerable absorptive capacity. As a consequence, only the directly connected impervious area would normally be expected to contribute runoff. Hence, summer peak flow rates in creek systems are invariably less than those for winter storms for impervious percentages less than those of single-family residential.

Impact of Re-Development on Watercourse Stability

If impervious cover is added through redevelopment, this results in a larger contributory area under summer rainfall conditions. Small storms that previously did not contribute runoff ... now result in runoff . (Reference: Figures 2-2 and 2-6).

Again, it must be emphasized that densification results in more runoff events per year. Of importance, channel erosion is a function of stream flow velocity. If a *threshold velocity* that formerly occurred infrequently now occurs frequently, the consequence is watercourse 'wear-and-tear'.

2.9 Mitigation of *Changes in Hydrology* at the Source versus On-Site

Identification of Alternative Approaches

Of the four factors limiting the ecological values of urban creeks, *changes in hydrology* can be viewed as the paramount factor. The reason is that the consequences of those changes progressively manifest themselves in the disturbance of riparian and aquatic habitat, and in the deterioration of water quality.

Address 'changes in hydrology' on a watershed basis, and there will be spin-off benefits in terms of mitigating the other three factors. The choices for stormwater management are summarized as follows:

- **On-Site:** Incorporate impervious area reduction measures and/or stormwater detention facilities at development sites to provide source-control.
- **Off-Site:** Bypass flows around high value creek reaches and/or construct regional detention ponds at strategic locations as an alternative to source-control.

The optimum strategy may be a combination of on-site and off-site measures. The more that can be done on-site, the smaller the regional facilities.

Sizing of Stormwater Detention Facilities

The focus is on those storms that occur 6 to 10 times per year (i.e. by definition, the *frequently occurring small storms*), and that have a peak flow rate roughly equal to 50% of the pre-development Q_2 (i.e. the runoff event with a 2-year return period). The following minimum criteria have been selected for detention facility sizing in the Stoney Creek watershed:

CONDITION	INPUT EVENT❶	RELEASE RATE
Redevelopment	Q_2	50% $Q_2$❷
New Development	Q_5	50% $Q_2$❸

❶ For post-development conditions.
❷ For original single-family residential condition.
❸ For pre-development land-use condition (e.g. forested).

Appendix A presents the documentation for the *Hydrology Workshop*, including a tabular summary of 'rule-of-thumb' detention volumes as a function of *MDP Level* and TIA (Total Impervious Area), that resulted in selection of the above criteria.

The distinction between the input events for redevelopment versus new development reflects the decision by the Steering Committee to provide add a safety factor for new development areas. The release rate varies as a function of TIA.

2.10 Summary of Findings

The Dual Focus of a Stormwater Management Strategy

A stormwater management strategy must deal with two distinct types of consequences related to the rainfall-runoff process. These consequences are described as follows:

- **Dramatic Impacts:** This refers to flood and erosion damage resulting from peak flows during major storm/runoff events.
- **Insidious Impacts:** This refers to the stream corridor 'wear-and-tear' resulting from the increased frequency-of-occurrence of higher rates of runoff during minor storm runoff events.

The traditional focus of drainage planning has been on flood impacts. In the 1990s, the spotlight has shifted to the insidious impacts.

Impact of Re-Development on Runoff Frequency

The two components of a stormwater management strategy are summarized as follows:

Impact	Hydrotechnical Focus	Return Period
Insidious	Frequently Occurring Small Storms	$\ll Q_2$
Dramatic	Infrequently Occurring Large Storms	Q_{10} and Q_{100}

For an urbanized watershed that is undergoing densification of land use, the incremental increases in peak rates for Q_{10} and Q_{100} are marginal. The main impact is on the increased number of runoff events per year that exceed a *threshold velocity* for watercourse erosion. Understanding this relationship is key to developing the hydrotechnical component of an integrated stormwater management strategy.

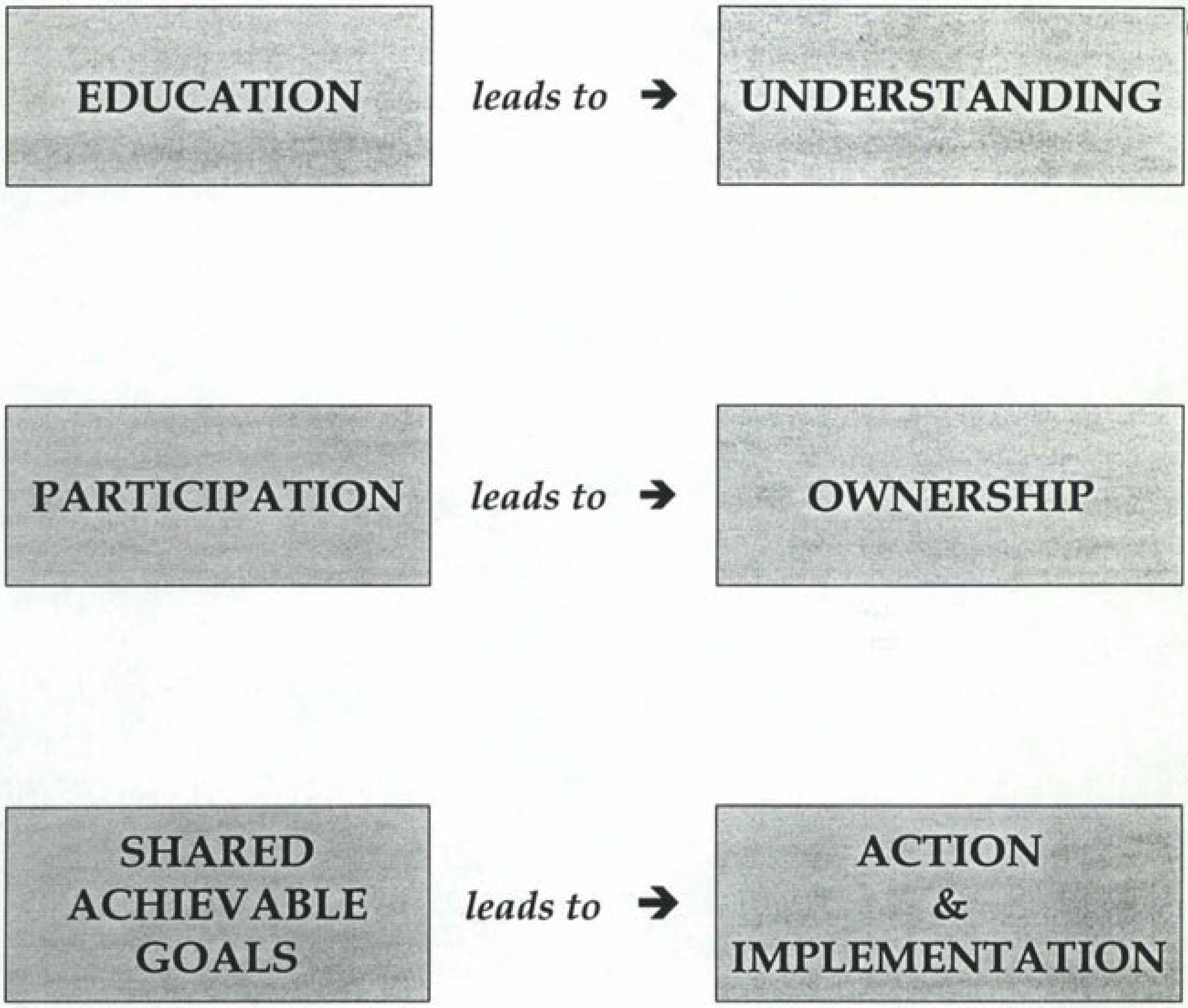
Flood Risk Management versus Environmental Risk Management

The purpose of *flood risk management* is to protect property by ensuring that the 'design flood' (i.e. Q_{100}) can be contained by creek channels and passed by culverts; whereas the purpose of *environmental risk management* is to protect ecosystems from being degraded by the insidious consequences of 'frequently occurring small storms' (i.e. considerably smaller than Q_2).

Further to the above, the function of stormwater detention facilities in the Stoney Creek watershed would be to mitigate the 'changes in hydrology' associated with the small storms. The objective would be to partially restore the natural hydrology by dealing with those storms that are equivalent to $0.5Q_2$, and that occur 6 to 10 times per year. It is also noteworthy that roughly 90% of the annual rainfall events likely have less than 2.5mm of rainfall. This is a manageable amount to infiltrate.

CHAPTER 3

CONCEPTUAL FRAMEWORK FOR DECISION PROCESS



THE ESSENCE OF PROACTIVE STAKEHOLDER INVOLVEMENT

FIGURE 3-1

3. CONCEPTUAL FRAMEWORK FOR DECISION PROCESS

3.1 A Perspective

Identification of Shared Community Goals

In the 1990s, it is essential that a stormwater management strategy have the support of the community. To this end, Figure 3-1 conceptualizes the essence of the stakeholder involvement process. This model is also applicable to the Steering Committee process, because a variety of perspectives need to be integrated in Reaching consensus on "shared achievable goals" for watershed and stream corridor management.

Six Steps to Making and Implementing Quality Decisions

Figure 3-2 illustrates a proven approach to decision-making for complex issues, and complements Figure 3-1. This flowchart emphasizes the need for a deliberate process that involves stakeholders in developing a shared vision. By incorporating feedback loops, this process also incorporates opportunities for *adaptive management*.

If the public and the elected officials have a shared vision for integrated stormwater and natural resource management, funding and implementation are far more likely to follow. With participation of the regulatory agencies in the visioning process, senior governments are far more likely to support a municipality's efforts and less likely to impose burdensome requirements.

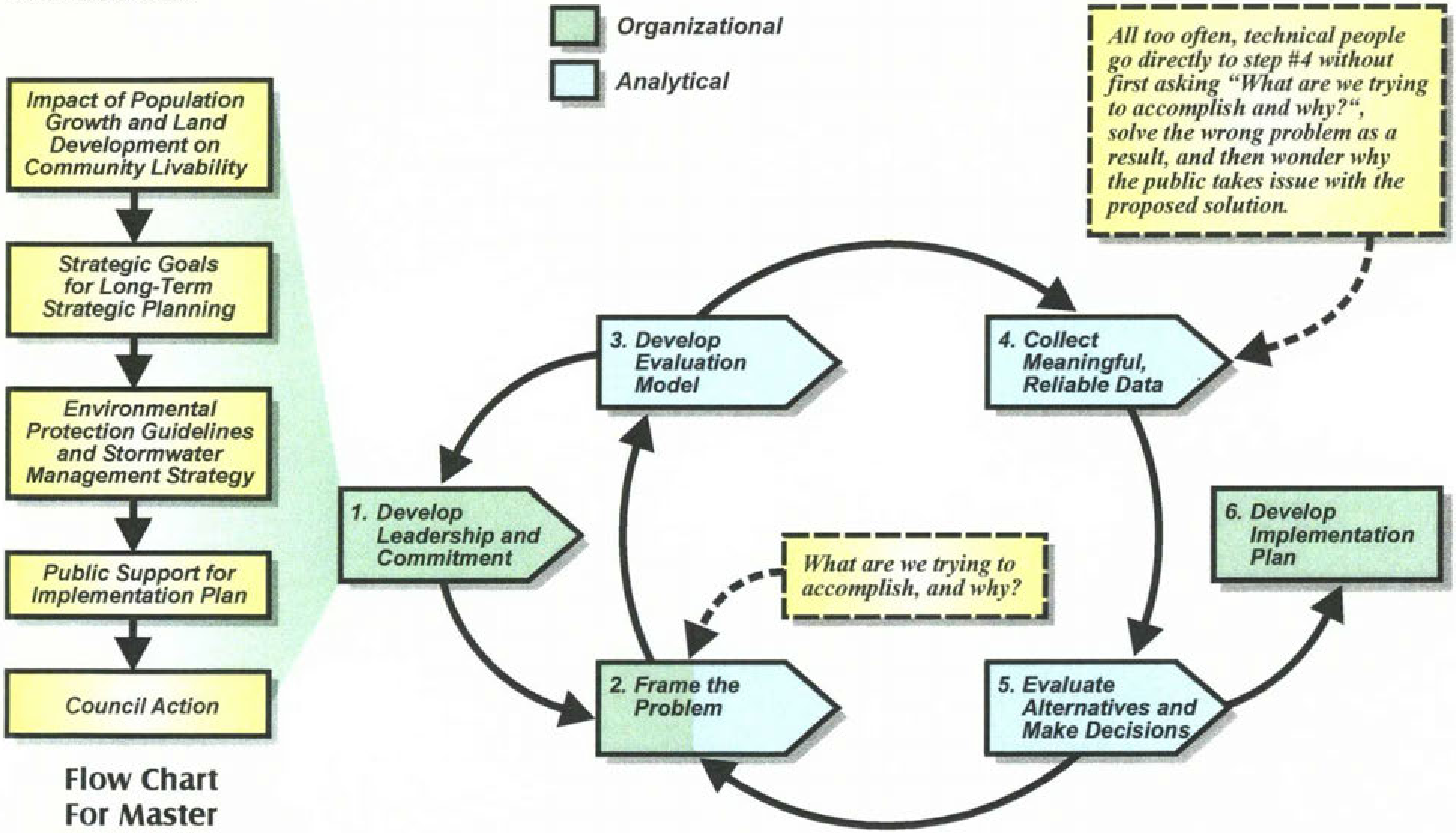
Integration with Master Planning Process

Figure 3-2 actually integrates two concepts for consensus-building and goal setting. The two parts of Figure 3-2 are described as follows:

- **Hierarchal Process**: The left side illustrates the flow path for successfully bringing forward a major initiative. First, there has to be a perceived need. This then establishes the goals in developing a strategy. Finally, implementation requires public support in order to generate political action.
- **Iterative Process**: The right side illustrates the six steps required to efficiently make and implement quality decisions. All too often engineers jump directly to *Step #4* (which is to collect data) without first having defined the problem and obtained commitment to the shared goals.

To be effective, a strategy must be based on a clear definition of the shared goals, and realistic expectations for achieving them. Our approach to the Stoney Creek stormwater management study is grounded in a commitment to this type of participatory decision process. Workshops and working sessions with the Steering Committee have facilitated this process.

1045-002\FIG3-2.CDR Jan.26/99



Flow Chart For Master Planning Process

KWL CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

Six Steps To Making And Implementing Quality Decisions

Figure 3-2

3.2 Workshops: A Forum for Feedback and Knowledge Transfer

Communication is key to developing effective partnerships. Workshops and working sessions provide a forum for the communication process. The objective is to stimulate the creative thinking of the workshop participants in addressing this fundamental question: *What are we trying to accomplish, and why?* The communication process for the Stoney Creek study involved five workshops and four working sessions. The focus of each workshop is highlighted as follows:

- **First Workshop - Customizing Hydrologic Criteria:** In early May 1998, the engineering representatives on the Steering Committee met with members of the Project Team to Reach consensus on the selection of engineering criteria for sizing stormwater detention facilities. The concept of *MDP Levels* was embraced in principle for sizing ponds as a function of release rates.

- **Second Workshop - Documentation of Aquatic Habitat Knowledge:** In late May 1998, members of the Project Team met with the *Stoney Creek Environmental Committee* to acquire undocumented biophysical information on the Stoney Creek system and to generally validate/update documented information that has been collected in the past. The information was compiled Reach-by-Reach.

- **Third Workshop - Evaluation and Selection of Achievable Elements of a Concept Plan:** In mid-August 1998, the majority of the Steering Committee met with the Project Team to evaluate possible options and solutions to urban runoff issues, and in so doing contribute to development of an acceptable stormwater management strategy to protect the aquatic resources in Stoney Creek.

- **Fourth Workshop - Strategy Development for Stoney Creek Integrated Stormwater Management:** In mid-September 1998, the full committee met with the Project Team to affirm and apply the 6-step decision process to select and assess the environmental protection and enhancement elements of a master plan for achieving a Level 3 MDP (Hold the Line) and then transitioning to Level 4 (Improve Conditions) over time.

- **Fifth Workshop - Strategy Finalization for Stoney Creek Integrated Stormwater Management:** In mid-October 1998, the full committee again met to review and finalize this report, and in so doing endorse the plan elements and strategy for moving forward with implementation of the study recommendations.

The five workshops were complemented by four half-day working sessions with the Committee. The latter provided timely opportunities for progress reporting by the Project Team, and for the Committee to provide feedback and direction early in the study process. Documentation is presented in Appendix B to provide a record of how the process unfolded. Of significance, the workshops were fundamental to successful application of the 6-step decision process.

3.3 Application of the Six-Step Process to Stoney Creek

Introduction

This section describes how the 'six-step process' as illustrated on Figure 3-2 applies to the decision process used for development of the *Stoney Creek Stormwater Management Strategy*. Each step is described in detail in the sub-sections that follow.

Step One: Assure Leadership and Commitment to the Decision and the Process

Leadership and commitment have been established through the formulation of a project Steering Committee, and approval of the process by the elected officials from each of the participating jurisdictions.

The steering committee comprises representatives from each of the municipalities with jurisdiction in the watershed, the GVRD and community representatives. Engineers and planners are present from the municipalities. Each jurisdictions elected officials have demonstrated commitment by approving and providing funding for the process.

The committee process provides an interim vehicle for gauging community values and community support with respect to a guiding philosophy for watershed and stream corridor management.

Step Two: Frame the Problem

The *Stoney Creek Stormwater Management Strategy* is being developed within the context of the overall *Brunette Basin Watershed Management Plan*. It has been called a "pilot within a pilot" project. Stoney Creek has been recognized as the most productive remaining sub-watershed within the Brunette Watershed and therefore worthy of the highest environmental protection.

Under existing management programs, the environmental values of the stream are declining. The numbers of successfully spawning and rearing salmon are declining. Flooding and erosion has increased. Water quality monitoring has shown high levels of nutrients, suspended solids, coliform bacteria and other pollutants. There are significant development activities occurring in the Stoney Creek sub-watershed that threaten the environmental values of the stream.

A plan is necessary to provide environmental protection while allowing continued development and redevelopment to occur. The land use patterns are well established and the Stoney Creek watershed is substantially developed. Thus, major changes in land uses are not realistic and are not addressed in this study.

The primary focus of this study is to identify Best Management Practices (BMPs), on-site requirements for new development and redevelopment, capital improvements and agency programs needed to achieve the desired goal.

Step Three: Develop Value Model and Formulate Alternatives

Goal Statement

The Task Group for the *Brunette Basin Watershed Management Plan* has developed a draft goal statement and corresponding objectives. These are drawn from the various OCPs for the participating jurisdictions. The OCPs are the official statements of policy and reflect the community values. The overall goal for the Brunette is stated below:

> **To protect or enhance the integrity of the aquatic and terrestrial ecosystems and the human populations they support in a manner that accommodates growth and development.**

This goal is equally appropriate for Stoney Creek. Another way to express this goal in terms of its application to Stoney Creek is to state that: The goal is to develop a master plan that protects property and allows economic land use while sustaining natural systems.

Fundamental Objectives

The set of nine objectives as formulated by the Brunette Task Group is presented below in four groupings:

CATEGORY	OBJECTIVES
Environmental	• Protect or enhance aquatic habitat • Protect or enhance terrestrial habitat • Protect or enhance bio-diversity
Social	• Optimize recreational opportunities • Minimize health and safety impacts related to flooding and water quality
Financial	• Minimize life cycle costs • Minimize property damage • Optimize regional-municipal cost and benefit sharing
Learning	• Increase scientific and management understanding

For consistency with the over-arching Brunette process, the set of nine objectives provide a frame-of-reference for the Stoney Creek decision process. Certain objectives are assumed to be mandatory minimal requirements. These include achieving the standards for protection from flooding, and addressing water quality issues that are toxic to fish or humans.

Alternatives must address these issues within the Stoney Creek watershed and must not simply pass the problem downstream. Beyond this, the selection of the level of environmental protection or enhancement becomes a local decision. The local decision must balance the benefits and costs to the local and regional community.

Identification and Evaluation of Alternatives

To facilitate the evaluation, a series of planning scenarios has been developed that corresponds to potential levels of environmental protection as follows:

- **Scenario A:** Status Quo Strategy for Stream Management (Level 2 MDP)
- **Scenario B**: Hold the Line and Accommodate Growth Strategy for Stream Management (Level 3 MDP)
- **Scenario C:** Enhance Aquatic Conditions and Accommodate Growth Strategy for Stream Management (Level 4 MDP)

These scenarios are described in Tables 3-1 through 3-3. With differing levels of effort and investment, the jurisdictions managing the Stoney Creek watershed could achieve varying levels of environmental protection.

The tables describe these levels, specific objectives to achieve the levels, measurable criteria to test achievement, and actions needed to achieve the desired results. Looking ahead to Chapter 7, Figure 7-1 illustrates the major capital elements corresponding to these scenarios.

Factors Limiting the Ecological Values of Urban Streams

Within the subject of environmental protection, a primary issue is the question of achievable levels of sustainable fish populations. Research has shown that urban development significantly impacts the abundance and diversity of fish populations. In order of importance, and as illustrated previously on Figure 2-4, the primary impacts to fish in most urbanizing watersheds are due to:

- changes to hydrology,
- loss of riparian corridors,
- loss of physical habitat and
- water quality degradation.

Tables 3-1 through 3-3 are organized to address these issues. These tables expand on the previously introduced objectives by providing performance measures for each of these issues, and include a summary of the actions needed to achieve the stated level of environmental protection.

Table 3-I: Status Quo Strategy for Stream Management
(Scenario A: Status Quo)

Continue current recommended management practices. Community values urban stream system for open space and aesthetic values. Water quality and flooding must not degrade downstream conditions. Accept that current trends in declining biological resources may continue.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	Increases to peak and duration of peak flows are partially mitigated.	Are regulations enforced? Trends of increased peak flows and duration of peak flows continue. Monitoring incomplete.	Enforce Existing policies and regulations for flow control from new development. Investments in capital facilities such as regional detention ponds and bank stabilization projects.
Riparian Corridor	Riparian corridors are partially protected.	Are regulations enforced? Trends of riparian loss continue at present rate.	Enforce Existing policies and regulations for riparian setbacks for new development
Aquatic Habitat	Loss of aquatic habitat is limited.	Are regulations enforced? Trends in aquatic habitat loss continue at present rate.	Enforce Existing policies and regulations for stream protection
Water Quality	Declines in water quality are minimized.	Are regulations enforced? Trends in water quality decline continue.	Enforce Existing policies and regulations for water quality for new and existing development

Table 3-2: Hold the Line and Accommodate Growth Strategy for Stream Management (Scenario B: Hold the Line)

Hold the line in the face of growth and downward trends. Community values stream system for its biological functions in addition to open space and aesthetic values. Community accepts that trout and hatchery supported salmon populations are a reasonable management goal and is willing to invest additional effort and funds to achieve this.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	No change in peak or duration of runoff from storm events.	Stream monitoring demonstrates that neither frequency nor duration of peak flows has increased. No net loss of forest cover. Effective impervious surface between 12 and 25%.	Requires increased standards for retention of forest, infiltration and detention of runoff, factors of safety and measures to address changes not captured by regulatory system. Zero discharge of runoff from 6 month return storm. No loss of wetlands or wetland function.
Riparian Corridor	No net loss.	Annual measurements and ground inspection reveals no net loss of riparian buffer width or vegetation. At least 60% of the stream corridor has a buffer of 30 meters on each side.	Requires stronger regulation for buffers, limits on clearing for existing properties, enforcement and compensation mechanisms.
Aquatic Habitat	No loss of habitat	Annual monitoring reveals that pool/riffle ratios, percent of fines in the sediment, large organic debris and benthic index of biotic integrity do not deteriorate. Use module 2 of the advanced stream habitat survey interpretation sheet and module 4 of the invertebrate survey interpretation sheet.	Requires stronger regulation for hydrology, riparian buffers and water quality. Requires annual program working with volunteers to construct habitat structures. No loss of wetlands or wetland functions.
Water Quality	No decline in water quality.	Water quality monitoring indicates that water quality does not deteriorate from existing conditions. Water quality is not toxic to fish.	Requires increased regulations and increase in educational program for residents. Increased enforcement of water quality violations. Capital improvements to contain spills and treat runoff from commercial areas. Response program for rapid containment and clean-up of spills.

Table 3-3: Enhance Aquatic Conditions and Accommodate Growth Strategy for Stream Management

(Scenario C – Improve Conditions)

Enhance Aquatic Conditions and accommodate growth. Community places high value on stream system and self-sustaining wild salmon populations. Community is willing to make substantial investments to achieve this goal recognizing that this goal may not be achievable.			
Goal	**Objective**	**Measurable Criteria**	**Actions Required to Achieve Goal**
Hydrology	Frequency and duration of peak flows is reduced	Annual review of monitoring data demonstrates that the peaks and durations of flows resulting from a six month and annual return interval storm event are not increased and that there is no increase in the peak flows from more frequent storms.	All of the above plus zero discharge of runoff from storms up to the two year return event storm. Capital improvements to increase regional detention and infiltration. Potential capital improvements to by-pass peak flows through entire system. Aggressive program to plant evergreen trees throughout the watershed.
Riparian Corridor	Additional riparian corridor is protected	At least 60 % of the riparian corridor is protected with a 50 metre buffer of undisturbed vegetation	All of the above plus aggressive program to purchase developed riparian areas, remove structures and re-establish native vegetation in buffers.
Aquatic Habitat	Additional aquatic habitat is created.	pool/riffle ratio is approximately 50/50, percent of fines in sediment is less than 15%, the Benthic Index of Biotic Integrity is at least 35.	All of the above plus aggressive program to construct and maintain aquatic habitat structures. Restore lost wetland functions.
Water Quality	Water quality improves	Water quality meets Provincial and Federal guidelines for all parameters.	All of the above plus aggressive program to build small scale treatment facilities at major stormwater outfalls.

Table 3-4: Decision Criteria to Select Strategies for Stream Management

NO.	OBJECTIVES OR DECISION CRITERIA AS ESTABLISHED BY THE BRUNETTE BASIN TASK GROUP	HOW IMPORTANT IS EACH DECISION CRITERION?❶	HOW WELL DOES EACH SCENARIO ACHIEVE EACH OBJECTIVE?❷ SCENARIO A (LEVEL 2 MDP) STATUS QUO, CONTINUED DECLINES IN FISH*	SCENARIO B LEVEL 3 MDP) HOLD THE LINE, SUSTAIN TROUT AND HATCHERY SALMON*	SCENARIO C (LEVEL 4 MDP) STRATEGY C: ENHANCE HABITAT, SUSTAIN WILD SALMON*
1.	Protect or enhance biodiversity*	very important	low	medium	high
2.	Protect or enhance aquatic habitat*	very important	low	medium	high
3.	Protect or enhance terrestrial habitat	moderate importance	low	medium	high
4.	Enhance recreation opportunities	moderate importance	low	medium	high
5.	Minimize health and safety impacts	very important	high	high	high
6.	Minimize Total costs❸	very important	high (no change in existing costs)	medium (increased costs)	low (high cost)
7.	Minimize property damage	very important	medium	high	high
8.	Increase scientific and management understanding	least important	medium	high	high
9.	Increase opportunity for public learning	least important	medium	high	high

* See Tables 3-1, 3-2 and 3-3 for refinement of these Decision Criteria and for more detailed descriptions of the scenarios.

❶ Based on the experience of the project team, three judgemental choices are provided for rating each objective: very important, moderate importance, and least important.

❷ Based on the experience of the Project Team, three judgemental choices are provided for rating each scenario: low, medium and high.

❸ By definition, "total costs" are based on present value analysis.

Application of Master Planning Levels

Three levels of potential environmental protection for fish are presented. These levels correspond to the 'planning levels' introduced in Chapter 1 (i.e. Table 1-2) and illustrated on Figure 2-3. Key points to note are highlighted below:

- *Level Two* (Table 3-1) would maintain the status quo for government programs. Existing regulations and procedures would continue and habitat values would continue their present downward trends.
- *Level Three* (Table 3-2) would sustain existing environmental conditions but would require additional programs and financial costs.
- *Level Four* (Table 3-3) would enhance existing aquatic environmental conditions but at substantial additional costs for regional facilities and increased requirements for on-site facilities to manage stormwater from new development.

Decision makers must choose from these levels by balancing the environmental, social and financial benefits against the financial costs and the risks of not achieving the selected objectives. The decision process to choose the level of environmental protection will be an iterative one and may result in selection of a combination of protection levels for differing portions of the watershed.

Application of Decision-Making Matrix

The decision criteria are the objectives. To decide which level of environmental protection is preferred, the decision-maker must determine how well each scenario achieves each objective and balance the trade-offs and conflicts. For example, the highest level of environmental protection will have the highest environmental benefits but will require the highest financial costs to developers and the community.

Each objective and each scenario is presented in matrix form in Table 3-4. With the matrix, each criterion can be considered for each scenario and the results can be visualized, compared and recorded. In workshop format, the Steering committee must evaluate and discuss each alternative and select a preferred approach.

The first column poses a question that requires a subjective answer. The question is: How important is each of the nine decision criteria as established by the Brunette Task Group. Three choices are provided in order to rate the criteria: very important, moderate importance, and least important. These could just as easily been given a numeric rating (i.e. 5, 3 and 1). However, we suggest that a numeric rating would be misleading with respect to the level of preciseness of a subjective analysis. Hence, the reason for descriptive categorizations.

Similarly, each decision-maker is asked for a subjective and judgemental answer to the question: how well does each scenario achieve each of the nine objectives? Three choices are provided for assessing and ranking each scenario: low, medium and high. Given the scenario definitions, the rankings may seem intuitively obvious.

Step Four: Collect Meaningful, Reliable Data

The first step in analyzing potential environmental benefits is to assess the current habitat values and water quality within the system. This has been accomplished through the use of an expert panel workshop, field investigations, water quality and quantity monitoring and modeling of the stream flows. The results of these analyses are described in subsequent chapters but summarized here.

Looking ahead to Chapter 5, Figure 5-1 describes the relative aquatic habitat values of each reach within Stoney Creek system. This figure shows where the highest value habitat is presently found and describes some of the limiting factors to fish habitat.

Analysis of this figure shows that the highest value habitat in the system is the Reach at the bottom of the system (between the Lougheed Highway and the confluence with the Brunette) and those portions of the stream within Tributary #3. Limits to habitat in other areas include barriers to fish passage, bank erosion along the main channel resulting from increased flows and loss of riparian corridor.

Step Five: Evaluate Alternatives and Make Decisions

Application of Professional Judgement

Using the data available, the next step is to evaluate the alternatives on the basis of the identified criteria and make decisions. It is anticipated that the decisions may reflect a combination of elements from the three scenarios and that they may be applied differently to each subwatershed. Because of the limited data available and the complexities of dealing with natural systems, each decision-maker must rely in part on their own informed, professional judgement to evaluate the alternatives.

At this point in the process, it is important to check back with leadership and other stakeholders and assure that they are still committed to the need, process, values and recommendations of the study.

Verification of Leadership and Commitment

Through this study, the Project Steering Committee has arrived at Step Five. Decisions must be made regarding selection of preferred alternatives. Then each participant must return to their respective constituencies and verify leadership and commitment. If necessary, adjustments may be required to the objectives, criteria or weighting factors and the evaluation process repeated. Or, additional data may be needed to reduce uncertainty regarding the outcomes.

Step Six: Develop Implementation Plan

This step is beyond the scope of the present study, and will be developed by the staff of the participating jurisdictions.

3.4 Elements of a Concept Plan for Stormwater Management

A Perspective on Understanding Fundamental Concepts

Reaching consensus on what elements of a master plan may be achievable requires a full and proper understanding of fundamental concepts related to:

- The impact of land use changes on hydrology, with emphasis on what 'zero runoff' from forested land actually means, and the implications for SFU.
- The vastly different approaches to mitigating and/or containing *frequently occurring* and *extreme* runoff events once forested land is urbanized.

Calibrated hydrologic models supplemented by monitoring programs provide enhanced insights into watershed response to rainfall under a range of antecedent conditions over the seasonal cycle. Development of an 'integrated stormwater management strategy' involves a multi-level thinking process that builds on the foundation provided by those insights. Chapter 4 elaborates on these technical issues.

Distinction between Conventional MDPs and Integrated Management Plans

The primary thrust of a conventional MDP (Master Drainage Plan) is on mitigating major peak flow events (e.g. Q_{100}), with particular emphasis on the conveyance adequacy of culverts and trunk sewers. Hence, the reference to an MDP being the *hydrotechnical component* of an integrated plan.

The hydrotechnical component can be viewed as one level of thinking, and is seemingly the most straightforward to address because it essentially involves a comparison of 'design flows' versus 'rated capacities'. This simplifies the task of preparing a plan of proposed remedial measures.

Further to the previous paragraph, the hydrotechnical component was dealt with early in the workshop process so that the Committee could then focus its efforts on those levels where participatory decision-making was required.

Integrated stormwater management involves the application of human values in making choices related to protection and preservation of ecosytems. Thus, a challenge for the Committee has been reaching consensus on 'shared values' that will be supported by the public so that an affordable stormwater management plan for Stoney Creek can in fact be implemented.

Evaluation and selection of the elements of a concept plan required interaction with the Steering Committee so that the implementation and affordability implications of various *MDP Levels* could be explored, explained, and resolved.

The Starting Point for Strategy Development

Figures A and B in Appendix C were presented to the Committee at the August and September workshops, respectively. They illustrated the possible elements of an *integrated stormwater management strategy*. The aquatic resources to be protected influenced the selection of choices for consideration by the Committee. Based on the findings of the aquatic habitat assessment, critical observations that provided a starting point for plan development are highlighted as follows:

- **Watercourse Condition:** The Stoney Creek system may be described as being in a state of noticeable decline since considerable bank erosion and channel instability are evident in the main stem.

- **Fisheries Resource Values:** The reaches from the confluence with the Brunette River to the Loughheed Highway are rated as having the best fisheries value. The next best Reach is the north branch of Tributary #3.

Given that 'changes in hydrology' is the most significant of the four factors impacting on the environmental values of urban streams, and in view of the limited opportunities for large-scale regional stormwater detention within the watershed, the only other options for mitigating these changes may be a combination of peak flow bypasses and on-site impervious area reduction initiatives.

Concept for Interception of Flows from Simon Fraser University

In the mid-1960s, an interceptor storm sewer was constructed down Gagliardi Way to the south branch of Tributary #3. (The system was sized for Q_{100}, and provides for baseflow return.) An off-site concept for accommodating proposed residential development within the Ring Road, while at the same time mitigating earlier 'changes in hydrology', is to extend the system upstream and downstream:

- **Upstream Extension:** Install a branch interceptor up the south half of the Ring Road to serve the new development area.

- **Outfall Location:** Re-direct the discharge from the Gagliardi Way sewer into Tributary #1 (instead of #3), and then into a second interceptor sewer system.

- **Downstream Extension:** Bypass the lower reaches of the main stem so that the best fisheries values can be preserved and protected.

A key consideration is that the off-site concept would make effective use of existing infrastructure. Another key consideration is that it would serve a two-fold purpose: mitigate a problem created by existing urbanization in the western part of the drainage basin; and enable new development to proceed. In Chapter 7, an on-site approach is considered.

Identification of Opportunities for Regional Stormwater Detention

For the western half of the drainage basin, the only potential opportunity for regional detention may be on an industrial site near the Cariboo Dam, in part because it is immediately adjacent to an existing park (as shown on Figure 7-1). The feasibility of utilizing this location is discussed in Chapter 7.

For the eastern half, on the other hand, there may be opportunities for regional detention at two or possibly three locations. Feedback on the feasibility and practicality of developing each site was solicited from the Committee during the workshops.

Optimizing Willingness to Pay versus Environmental Consequences

The purpose in presenting the elements of a Concept Plan was to stimulate discussion among the Committee members regarding the capital cost implications and achievability of the 'hold the line' goal of a *Level 3 MDP*. While definitive cost estimates were not available for the August and September workshops, the Committee was able to judge the order-of-magnitude cost of proposed elements.

From the perspective of the Project Team, it was helpful that the facilitated discussion provided a basis for assessing the likely acceptability of various elements.

Identification of Inter-Municipal Partnership Issues

An issue that may need to be highlighted through the political reporting process is the impact of possible future re-development and land use densification in Coquitlam on the fisheries resource within Burnaby.

The only potential site for regional stormwater detention is situated within Burnaby. Unless an impervious area reduction program can be successfully implemented in conjunction with re-development, this raises the issue of the upstream municipality taking responsibility for funding construction of facilities in a downstream jurisdiction.

Integration with Brunette Watershed Management Plan

As noted previously, the Stoney Creek process is viewed as a 'pilot program within a pilot program' because the intention is to apply the 'Stoney Creek model' to other sub-catchments within the Brunette River system. Similarly, the 'Brunette model' could be applied to other urban drainage systems within the region.

Given this frame-of-reference, the strategy for Stoney Creek must be compatible with the overall strategy for the Brunette. An holistic approach is therefore necessary when evaluating the acceptability of stormwater management choices: for example, discharging bypassed peak flows into the Brunette, because there may be a concern regarding the possible impact on fisheries habitat in the Brunette.

3.5 Summary of Findings

A Perspective

The purpose of this chapter has been to show how the 'six-step process' as illustrated on Figure 3-2 has been applied. The objective in documenting 'how to decide what to do' is to facilitate an understanding by others as to how the elements of a master plan for integrated stormwater management were identified, evaluated and selected.

Figure 3-2 is a key graphic because it conceptualizes a proven approach to decision-making for complex issues. Of the six steps, five are applicable to the present study. The final step is for the municipal staffs to develop individual implementation plans that are consistent with direction provided by this study. Table 3-4 is therefore an important deliverable because it presents weighted decision criteria in matrix form.

Application of Decision Criteria

Table 3-4 captures the key elements that drive the decision-making process for Stoney Creek within the overarching framework provided by the *Brunette Basin Watershed Management Plan*. The Brunette process has established a set of nine objectives to guide stormwater planning. The Stoney Creek process has then developed three scenarios corresponding to three potential levels of environmental protection. Given the foregoing frame-of-reference, Table 3-4 brings together the objectives and the scenarios by posing two fundamental questions that require the application of professional judgement in lieu of hard data:

- **Question #1:** How important (on a relative and judgmental scale) is each of the nine objectives?
- **Question #2:** How well does each scenario achieve each of the nine objectives (again, on a relative and judgmental scale)?

Table 3-4 presents the philosophical underpinning for moving in a direction that is keyed to 'holding the line' as an immediate minimum goal, and 'improving conditions' over time as an ultimate goal. However, a reality that may inevitably determine the acceptability of a recommended stormwater management strategy is that Objective #6 (Minimize Total Costs) to a large extent offsets the other eight.

A Look Ahead

In Chapter 7, the elements of a Concept Plan as finalized in consultation with the Steering Committee are presented. This includes bringing forward Table 3-4 in order to apply the decision criteria to each of the elements. Given the above perspective regarding Objective #6, it underscores the over-riding importance of 'willingness to pay' by the community in deciding whether the goal as articulated by the Brunette Task Group is in fact achievable.

CHAPTER 4

RESULTS OF
DRAINAGE FACILITY ASSESSMENT

4.0 RESULTS OF DRAINAGE FACILITY ASSESSMENT

4.1 Background

The focus of this chapter is on mitigating flood and erosion damage resulting from peak flows during major storm/runoff events (e.g. 100-Yr Flood). The objective is to establish a basis for *flood risk management*, with emphasis on a program for culvert rehabilitation/replacement (as discussed in Chapter 7). To this end, the scope of this chapter is four-fold:

- **Condition of Creek Channel System:** Summarize observations noted during field reconnaissance surveys and assess the relative stability of the Main Stem and tributaries.
- **Modelling of Rainfall-Runoff Response:** Describe the approach in first building a computer model, then validating it with actual storm events, and finally generating design flows for purposes of analysis.
- **Hydraulic Adequacy of Drainage System:** Compare the design flows with the rated capacities of existing culvert installations and channel cross-sections to assess the potential for flood overflows.
- **Risk Assessment for Creek Channel Crossings:** Assess the physical adequacy and acceptability of culverts, and consider the likelihood and consequences of a blockage.

This chapter is complemented by two appendices that document the results of the watercourse investigation program (Appendix D) and the rainfall-runoff modelling (Appendix E).

4.2 Condition of Creek Channel System

Figure 4-1 illustrates the reach designations for the Stoney Creek System. The Main Stem is classified into eight reaches, of which six are in Burnaby. The Main Stem has three western tributaries that extend up Burnaby Mountain. Figure 4-1 also identifies erosion and sedimentation locations.

A hand-held GPS (ground positioning system) was used to accurately record these locations and integrate the data with GIS for documentation purposes. Appendix D provides a comprehensive inventory of watercourse conditions and hydraulic structures. It also identifies suggested action items.

Erosion is particularly noticeable in the Main Stem between Beaverbrook and Broadway. In the upper half of this section, extensive channel bank stabilization work has been completed over the years. Severe erosion near Beaverbrook resulted in closure of a park trail in the past year. Chapter 5 includes an assessment of erorion and sedimentation from a fish habitat perspective. Significant sites are noted on Figure 5-1.

LEGEND

R8	Reach Number
T2	Tributary Number
	Watershed Boundary
	Current Erosion Sites
	Erosion Site With Adequate Bank Protection

KWL–CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

500 250 0 500

Scale in Metres

PROJECT No.	DATE:
1045-002	DEC. 31, 1998

REACH DESIGNATION FOR STONEY CREEK CHANNEL SYSTEM

FIGURE 4-1

4.3 Modelling of Rainfall-Runoff Response

Model Selection and Configuration

The RUNOFF block of the SWMM model was selected for hydrologic modelling of the urban and undeveloped portions of the watershed because it is a physically-based model. Having all undeveloped and developed areas modelled in SWMM provides more flexibility for the hydraulic modelling part of the program.

The watershed was discretized into roughly 100 drainage areas for analysis. The resulting flows were routed through the EXTRAN block of SWMM. Appendix E contains a pipe and node diagram and model sub-boundaries for the complete network.

Application of Design Rainstorms

Design storms were developed based on Atmospheric Environment Services (AES) statistical distributions for the Pacific Coast using historical rainfall summaries from the Burnaby Mountain station. Design storms were developed for storm durations ranging from 1 to 48 hours.

In consultation with City of Burnaby staff, the 30th percentile distribution was chosen for durations less than 6-hours, and the 50th percentile for six hours and greater.

The design storms were run through the SWMM model using saturated ground conditions because history has demonstrated that major winter storm events are usually preceded by significant rainfall activity. This in turn will saturate the basin prior to storm event, effectively removing most of the assimilative capacity of the soil and vegetation.

The 1-hour AES storm usually produces the largest flows. However, the actual rainfall events that make up the points derived for the 1-hour storm on the IDF curve are typically dominated by high intensity, convective activity that occurs mostly under non-saturated soil conditions.

A sensitivity analysis was undertaken varying the preceding soil moisture content, and results showed that (other than for one sub-catchment) where the impervious area is high, the 1-hour storm does not govern. As a result, the flows developed for the saturated 1-hour storm were not applicable in the vast majority of the Stoney Creek sub-catchments.

Appendix E includes tables showing flows from using the key 1, 2, 6, 12, and 24 hour design storms assuming fully saturated ground conditions. In most cases, maximum peak flows were generated by the 6-hour storm.

Validation of Model

Normal practice is to first calibrate and then verify a computer model on the basis of a hydrometric data collection program that yields concurrent rainfall and streamflow data for a series of storm events. Calibration is confirmed through verification. Budget limitations and data availability meant that it was only possible to 'validate' the computer model. Full calibration and verification was deemed to be outside the study scope.

Based on the Government Road streamflow station, the hydrographs for three events were used for model validation under both summer and spring conditions. The objective was to establish a level of confidence in the model output.

Figure 4-2 shows the July 3rd 1998 event. Although the simulated results closely resemble the recorded hydrograph, the flow is actually 25% higher due to the groundwater component. For spring/summer events, SWMM's groundwater algorithm was turned off due to uncertainties in seasonal soil saturation values.

Figure 4-3 shows the results for August 15th 1997 spring event. Again, groundwater was turned off. Therefore, the simulated results are slightly higher than the actual.

The higher simulated flows could be the result of inaccuracies in the stage-discharge curve or an EIA less than the TIA. The model should therefore be calibrated once better peak flow data are available for the Government Road Station.

Experience has shown that for larger storm events, rainfall variation and differences between TIA and EIA are less relevant due to the magnitude of the events. On that basis, one would expect the existing model to provide reasonable flows based on a level of accuracy demanded of uncalibrated models in general.

Furthermore, the design flows derived in this report will be more conservative than the values derived by a calibrated model. Without more accurate flow measurements, however, it would be unreasonable to adjust any of the model parameters at this point.

Generation of Design Peak Flows

Figure 4-4 shows the results for the January 29th 1997 winter event. This event was regionally significant, and was the largest of a series of storms during a record wet winter, and had a rainfall return period rating of about 1 in 25 years (i.e. based on the records for the Burnaby Mountain station).

On the basis of three validation events, the model was run with the 2, 10, 25 and 100-year design storms (at the 6 hour duration) to generate preliminary design flows for system analysis. Appendix E includes tables that list the output for these storms. These results include the groundwater component due to fully saturated soil.

Validation of Computer Model Using July 3, 1997 Rainfall Event

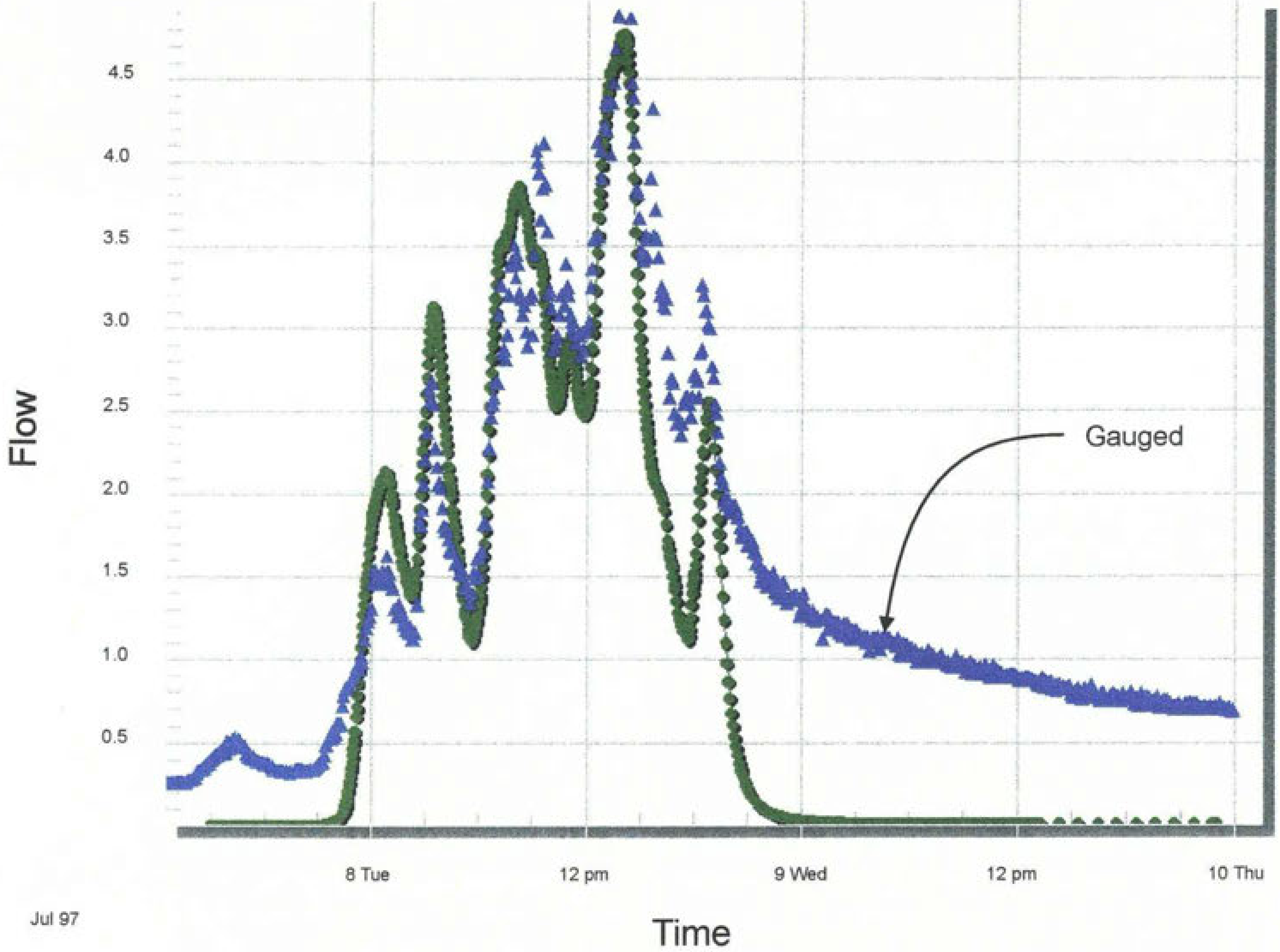


Figure 4-2

Validation of Computer Model Using April 15, 1997 Rainfall Event

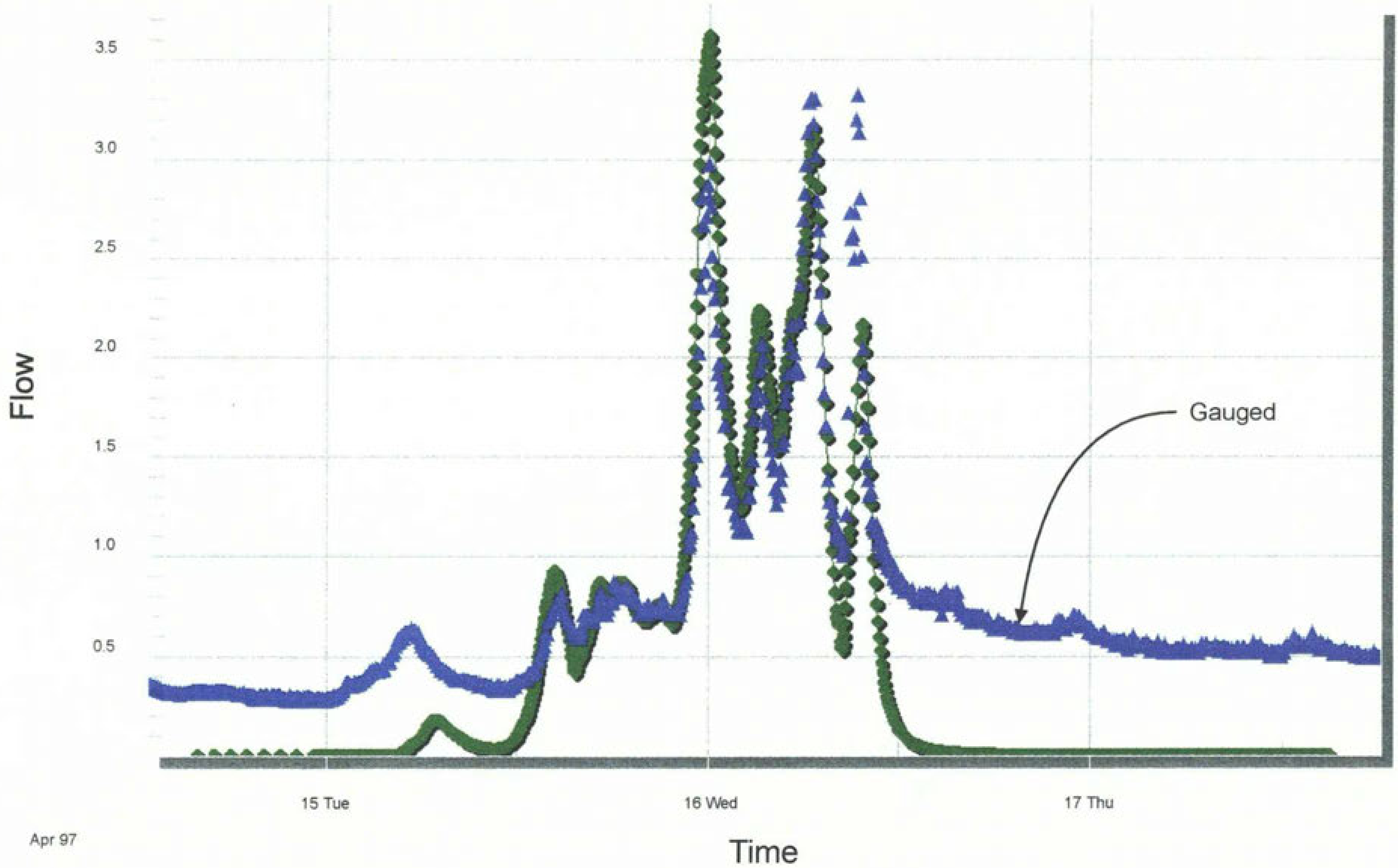


Figure 4-3

Validation of Computer Model Using January 29, 1997 Rainfall Event

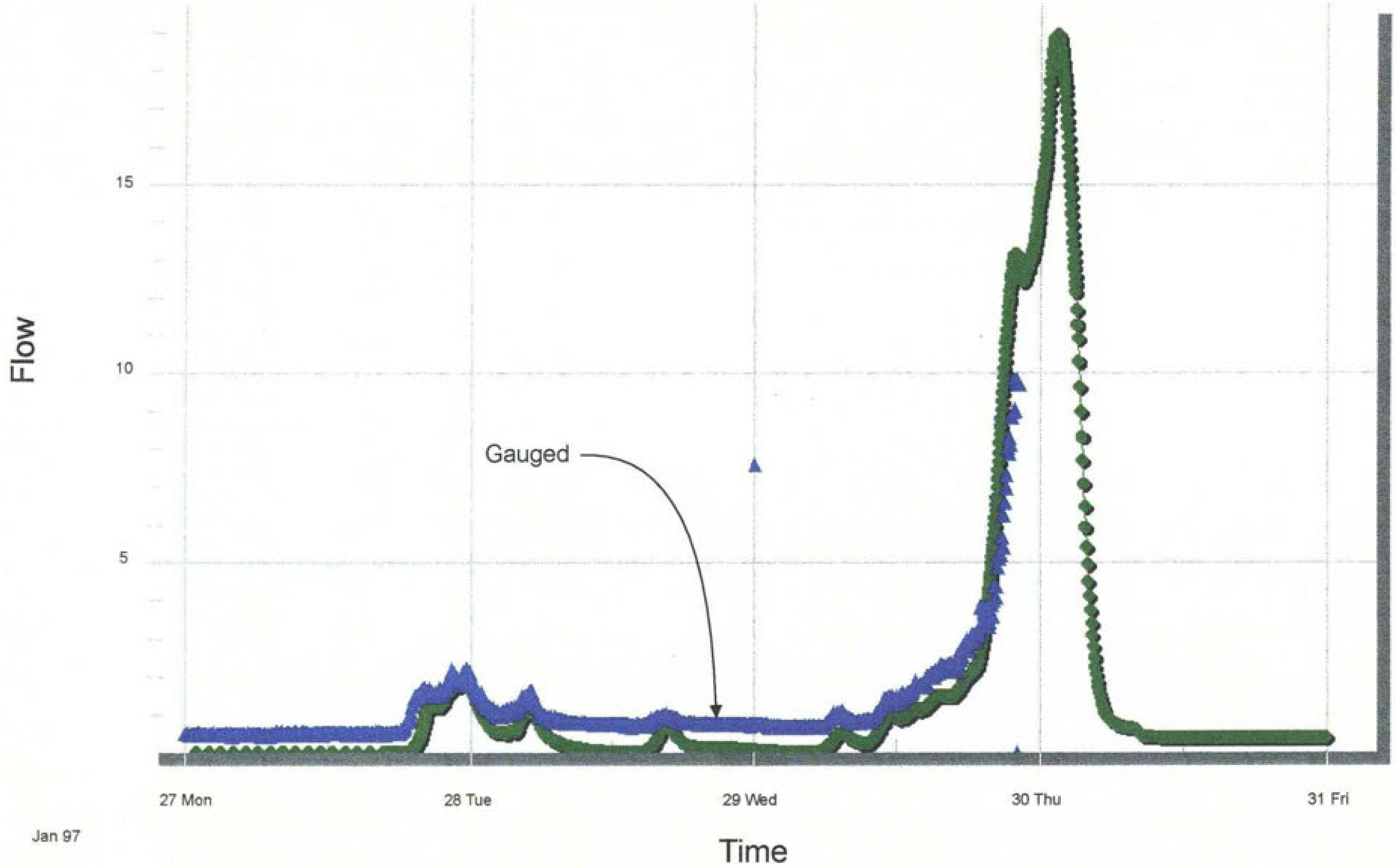


Figure 4-4

Comparison of Actual versus Design Storm Flows

Based on running the same parameter values in the validated (albeit uncalibrated) model, and for the Government Street monitoring location, the following table provides a comparison of the January 29th 1997 event versus the flows generated by applying AES design storm distributions:

Recorded Flow for January 29th 1997 Event (25-year rainfall)	Design Flows Generated Using AES Storm Distribution	
	For Q_{10}	For Q_{25}
18.6 cms	18.5 cms	21.4 cms

This comparison provides a check on the validity of using AES storm distributions for estimating design events. In other words, the difference between the actual January 29th flow and the theoretical Q_{25} (i.e. 18.6 versus 21.4) is mostly due to the makeup of the storm distribution, which we consider to be reasonable (considering that the actual is roughly 90% of the theoretical).

Impact of Upstream Hydraulic Restrictions

It should be noted the flows in Appendix E were derived based on not removing any upstream restrictions in the system. These flows represent the preliminary design flows for the 2, 5, 10, and 25-year return periods. However, for major culvert installations it was judged that the 'unrestricted flow' values should be used in order to address a culvert replacement scenario. For example, if an upstream culvert became surcharged under a particular design storm such that flow was routed to overland flow paths, the culvert was upgraded to accommodate the storm.

This provides a further factor of safety on the design flows derived at the lower points in the system. If improvements are made to these facilities, the higher numbers will be realized.

To demonstrate the sensitivity of removing the upstream restrictions, the following table has been developed:

Operating Condition	Design Flow Generated Using AES Storm (cms)	
	Q_{100}	Q_{25}
With Restrictions	25.4	21.4
Without Restrictions	32.9	27.6

The above table shows that the flows will increase roughly 30% as the upstream restrictions are removed from the system. This assumes the culverts will be progressively replaced and upsized over time. Looking ahead to the next section, both the 'unrestricted' and 'restricted' Q_{100} flow values are presented in Table 4-2 for completeness.

4.4 Hydraulic Adequacy of Drainage System

Interference with Creek Processes

It is really only in the past decade or so that municipalities have begun to recognize the importance of adopting a risk-based philosophy for culvert design. The significance of this statement is that culvert installations often interfere with natural creek processes, either by constricting or restricting the channel cross-section. This results in potential liability in the event of culvert failure and/or overtopping.

Further to the last sentence, it is rare that roadfill embankments are designed as water retaining structures. Hence, the concern is that culvert surcharging (due to either a blockage or capacity limitations) can result in ponding above the culvert that in turn results in seepage flow through the embankment, that in turn can result in piping failure commencing at the toe of the downstream face of the roadfill.

It must be emphasized that the assessment of hydraulic adequacy is merely the first step in a 2-step approach, with the second step being the assessment of physical adequacy. Applying a risk-based philosophy, practical considerations ultimately govern culvert effectiveness.

Given this overview, the purpose of this section is to summarize the results of the comparison of design flows versus rated capacities. This sets the stage for the risk analysis in the next section. This section also presents the results of the storm sewer capacity assessment. In addition, a perspective is provided on the floodway capacity.

Selection of Return Periods for Capacity Assessment

Generally accepted municipal practice in British Columbia for assessment of culvert adequacy is the Q100 criterion. Looking back, it is interesting to reflect on the evolution of accepted practice over the past three decades.

Until the 1970s, municipalities in the Greater Vancouver region typically applied Q_{25} when sizing culverts. The shift from Q_{25} to Q_{100} was driven by the consequences of a series of major region-wide flood events during that decade, in particular the July 1972 Flood that resulted in a major washout of the Upper Levels Highway on the North Shore.

The GVRD is responsible for maintenance of the Main Stem of Stoney Creek, and continues to apply Q_{25} as its standard-of-service. It would therefore seem timely for the GVRD to reassess the acceptability of this standard in light of current practice in member municipalities. In addition, and in view of the advances in hydrologic modelling in recent decades, it may also be timely to reassess whether the return period ratings for the original Q_{25} design flows should in fact be revised upwards.

Assessment of Culvert Installations on the Main Stem

Figure 4-5 identifies all existing hydraulic structures on the Main Stem and tributaries. It also presents the results of the capacity assessment (i.e. the comparison of design flows versus rated capacities). Based on good design practice, the 'rated capacity' corresponds to the 'no surcharge' operating condition.

The definition of what constitutes 'good practice' reflects practical experience that underscores the importance of maintaining a smooth flow condition through culverts to minimize the degree of interference with creek processes. Minimizing interference implicitly requires preservation (or improvement) of the cross-sectional area of the natural waterway.

The concern over culvert surcharging was highlighted in the Provincial inquiry into the 1972 washout of the Upper Levels Highway. One of the findings of the investigation into design practices was the reliance on manufacturers' nomographs for culvert sizing. Furthermore, the investigation revealed the flaw to be the assumption that culverts could be surcharged to pass the design flow.

The *Guidelines for Effective Culvert Design* as presented later in this chapter evolved from the findings of the 1972 inquiry. In applying the guidelines, and in assessing the 'surcharged versus no surcharged condition,' two paradigms need to be considered:

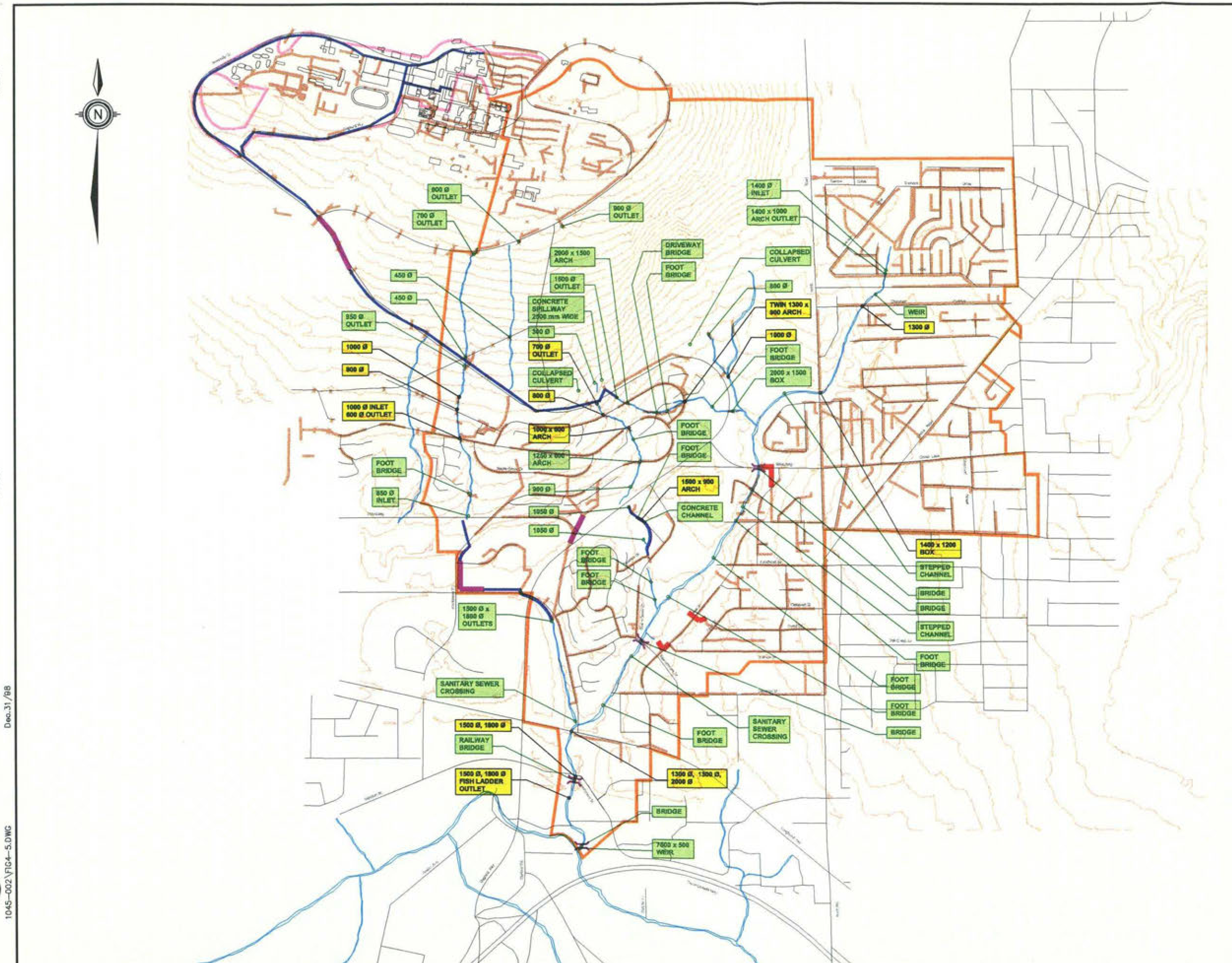
- **Existing Culvert:** Rate the culvert on the basis of 'no surcharging,' but assess the acceptability of the installation on the basis of a 'tolerable surcharge,' recognizing that practical considerations may ultimately determine whether it is financially feasible to replace an undersized culvert.

- **Proposed Culvert:** Design new installations on the basis of no surcharging, and maintain a smooth flow condition.

Further to the above, and for a culvert with inlet control, it is possible to fully utilize the hydraulic capacity of a culvert by adding a flumed entrance structure for flow acceleration. The explanation is that conventional culvert hydraulics is based on a ponded condition, partial pipe flow, and zero velocity initially. However, this approach conflicts with the requirements for fish passage.

Of the six culvert installations along the Main Stem, only one can pass Q_{100} without surcharging. Culvert performance has been modelled to assess the implications of these flow constrictions. On the one hand, surcharging does attenuate the peak. On the other hand, culvert installations are not designed as water retaining structures.

Before proceeding with a culvert replacement program, it is suggested that any implementation strategy be keyed to a calibrated and verified model of Stoney Creek so that the potential implications of proposed changes can be thoroughly assessed.



LEGEND

- Minor Tributary Area Boundary
- Major Tributary Area Boundary
- Contour In Metres
- 1300 Ø — Hydraulic Structure Location (And Size)
- Major Watercourses

MINOR DRAINAGE FACILITIES (Q10)

- Storm Sewer
- Surcharged Storm Sewer At Q10

MAJOR DRAINAGE FACILITIES (Q100)

- Surcharged Trunk Sewer At Q100
- Storm Trunk Sewer
- Capacity < 100 Year (Assuming HW = Diameter)
- Capacity > 100 Year

KWL CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

500 0 500
Scale in Metres

PROJECT No.	DATE:
1045-002	Dec. 16, 1998

INVENTORY AND
CAPACITY ASSESSMENT
OF DRAINAGE FACILITIES

FIGURE 4-5

1045-002\FIG4-5.DWG Dec.31/98

Assessment of Culvert Installations on the Tributaries

There is a total of 17 culvert installations along the three tributaries. Of this number, twelve are undersized for Q_{100}. By allowing a surcharge of between 1m and 2m, however, all but one installation could pass Q_{100}. Based on an assessment of overflow routes, surcharging should be acceptable.

Assessment of Storm Sewers

Figure 4-5 also shows the storm sewer network. The criterion for assessing sewer adequacy is Q_{10}. Storm sewers generally have capacity to convey Q_{10}. Those that surcharge are highlighted in red. The preciseness of the as-constructed data is an important consideration when analyzing system capacity.

Surcharging (or even overflow at manholes) may in some cases be necessary to pass Q_{10}, provided it does not result in basement flooding. If trunk sewer capacity has been adequate to handle even the major storms of record, this would lead to the conclusion that sewer surcharging is acceptable.

Of relevance, considerable effort has been invested in field-checking the acceptability of storm sewer overflows. As discussed with the Steering Committee, there is what the model tells the analyst. And then there is the application of judgement to determine an appropriate course-of-action.

Field-checking involved reconnaissance surveys to investigate overflow routes, and the potential consequences/risks of allowing overflows. In this regard, a storm sewer system is implicitly 'designed to fail' when the flow associated with a major storm event exceeds the nominal hydraulic capacity of the pipe.

As the result of applying judgement to reflect feedback provided by the individual municipalities on the acceptability of surcharged and/or overflow conditions, the potential scope of a storm sewer upsizing program was reduced from six projects encompassing all three cities, to a single project on Production Way in Burnaby.

Assessment of Floodway Capacity

Application of the EXTRAN block of SWMM is analagous to watching a movie in terms of the manner in which the peak flow is modelled along the channel system.

The key finding is that culvert installations in the lower reaches of the Main Stem are major constrictions. This means that culvert installations would overtop. Hence, an analysis of flood elevations may not be relevant until basic decisions are made with respect to a culvert replacement program.

4.5 Risk Assessment for Creek Channel Crossings

Hydraulic versus Physical Adequacy

The adequacy of a culvert installation can be assessed on the basis of two criteria:

- **Hydraulic Adequacy:** By definition, a simple comparison of rated capacity versus design flow.
- **Physical Adequacy:** By definition, a qualitative judgement regarding physical constraints that may adversely impact on hydraulic adequacy.

Based on long-term experience, the governing criterion is almost always *physical adequacy*, with hydraulic considerations usually being of secondary significance. The assessment of physical adequacy becomes key input in a risk analysis that considers the consequences of a blockage.

The Spectrum of Creek Processes

Figure 4-6 illustrates the spectrum of creek processes. The Stoney Creek system is characterized by *floods* and *debris-laden floods.* Since upstream activities/occurrences have downstream consequences, it is necessary to consider the risks associated with debris/bedload movement, and the consequences in the event of a culvert blockage.

Potential for Culvert Blockages

Culvert blockages are the primary cause of drainage problems, especially on small watercourse. The cause can usually be traced back to two sources:

- Erosion of bedload material, including gravel.
- Transport of floatable debris, such as branches and brush.

On small channels, even leaves and branches can have a considerable impact in contributing to culvert blockages, particularly in situations where culvert entrances are constricted.

A Perspective on Watercourse Erosion

Erosion of a creek channel is a natural and ongoing process. Eroded material is constantly moving along the channel bottom. As the magnitude and frequency of streamflow increases, so does the rate of bedload movement. A small increase in velocity results in a large increase in the size of material that can be moved (i.e. because the size moved varies with the sixth power of velocity). Erosion of the channel bed can trigger downcutting that results in undermining of channel banks, and this in turn contributes debris.

1045-002\FIG4-6.CDR

Spectrum of Creek Processes

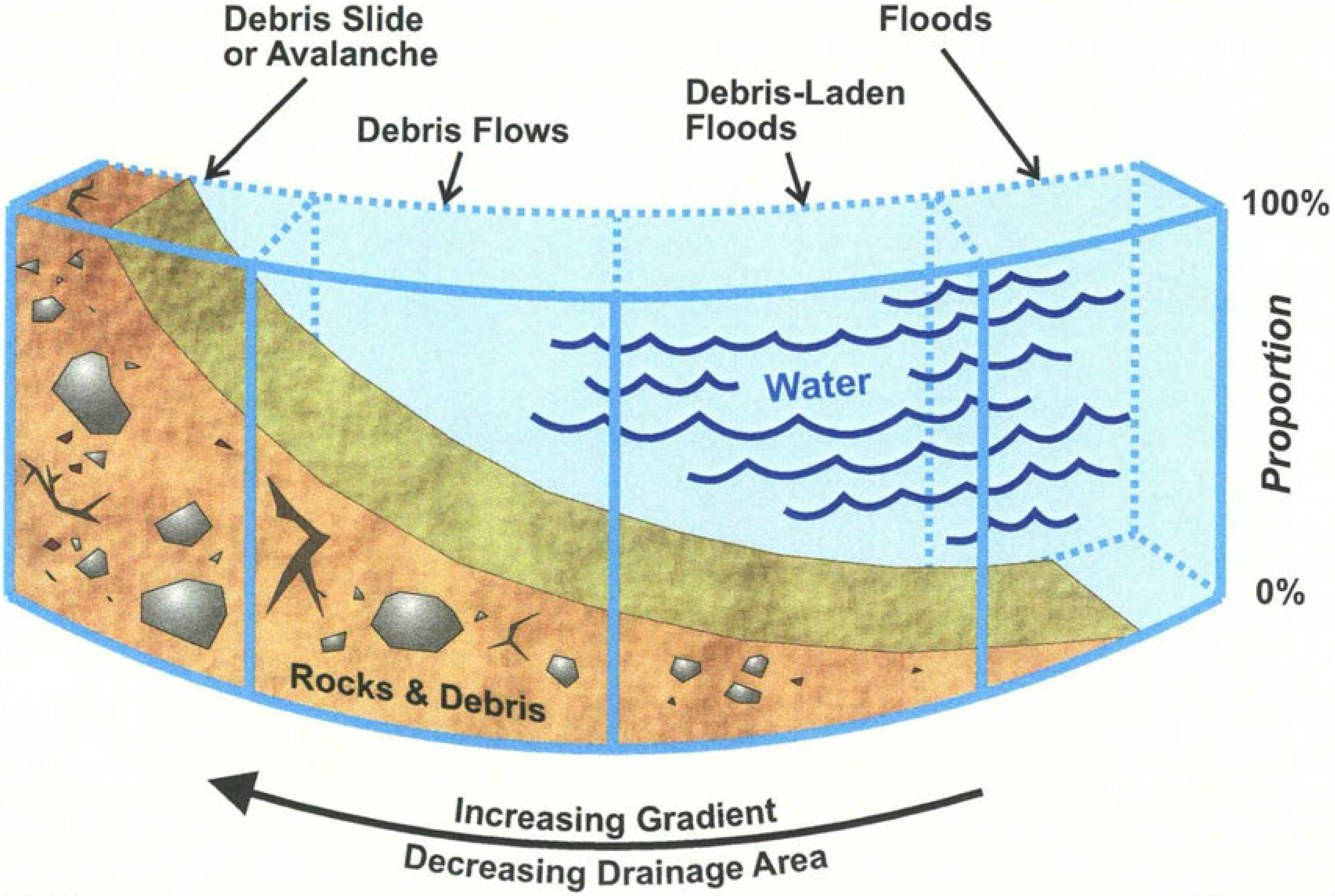


Figure 4-6

Process for Assessment of Physical Adequacy

Culvert assessment involves a 3-step process as summarized below:

- **Conformance with Design Guidelines (Step #1):** Assess the overall conformance of an existing installation with a set of guidelines for good design.
- **Vulnerability to Blockage (Step #2):** Assess the vulnerability, and the probability of culvert failure due to a blockage. The potential for a blockage reflects the bedload/debris characteristics of a creek.
- **Consequences of Failure (Step #3):** Assess the consequences of a culvert failure due to a blockage. The consequences can be two-fold: structural failure of a roadfill; and flood/debris overflow onto downstream properties.

Table 4-1 lists a set of nine guidelines that provide a basis for effective culvert design, and that can also be used to qualitatively assess the adequacy of existing facilities as *poor, fair, good* or *excellent.*

Guiding Principle for Culvert Design: Maintain Waterway Opening

Historically, drainage problems on creeks have resulted from interference with the natural system, with culvert installations being the primary cause of interference. A key reason for culvert-related problems is that designers typically over-emphasized the importance of *design flows,* and ignored the practical considerations that ultimately govern culvert performance.

A guiding principle for culvert design should be to preserve or improve the cross-sectional area and gradient of the natural waterway. In other words, a smooth flow condition should be maintained through culvert installations to minimize the degree of interference with creek processes.

Decision-Making Matrix for Culvert Replacement

Table 4-2 is a matrix that integrates the results of the assessment of hydraulic adequacy, physical adequacy and fish passage for each culvert installation. In effect, it is a decision-making matrix for culvert replacement.

On the basis of the findings as summarized in Table 4-2, four of the 27 culvert installations in the Stoney Creek channel system should ideally be replaced. All four are in the Main Stem. The most critical location is at Government Road because it must pass the total flow for the watershed.

Further investigation is required to develop a strategy for the Lougheed location, mainly because it is a major earthfill. One possibility may be to re-route flow via the bridge opening for the railway right-of-way.

TABLE 4-1

GUIDELINES FOR EFFECTIVE CULVERT DESIGN

No.	Description
1.	Maintain line and grade of creek channel.
2.	Maintain the waterway opening by bridging the creek channel.
3.	Construct inlet structure to provide direct entry and accelerated velocity.
4.	Ensure that it can pass trash, small debris and bedload material.
5.	Install debris interceptor upstream to provide protection from large debris.
6.	Provide scour protection to prevent undermining of the outlet structure.
7.	Incorporate provision for an overflow route in the event of a worst case scenario
8.	Provide equipment access for ease of maintenance (debris removal).
9.	Consider environmental issues, such as fish passage.

Integration of Ecological Considerations

Of the nine guidelines identified in Table 4-1, the first eight are hydrotechnical in nature. The ninth focuses on environmental issues, notably fish passage. Similarly, the first two pages of this section have addressed risk management issues from a hydrotechnical perspective.

Given the foregoing introduction, the purpose of this concluding page is to integrate ecological considerations that flow from Guideline #9. The focus is two-fold:

- **Conditions at Culvert Installation:** Is the culvert a barrier to fish passage? Would removal of the barrier enable access to upstream habitat? What is the relative value of the habitat?
- **Conditions in Upstream Channel:** Is upstream instability (that results in a potential for culvert blockage) itself the consequence of watercourse 'wear-and-tear' due to the increased frequency of the small runoff events?

The two scenarios are linked. A decision to invest in culvert rehabilitation or replacement to provide fish passage should therefore reflect an understanding of watershed processes as well as creek processes. There is a limited benefit if access is to be provided to habitat that is at risk due to *changes in hydrology.*

For the three culvert installations on the Main Stem between the Brunette and the Lougheed Highway, only the triple culverts at Lougheed have been identified as not meeting fish passage objectives. Yet fish do make it through under certain flow conditions.

For the 17 culvert installations along the three tributaries, only two have been categorized as 'fish-friendly.' Both are on Tributary #3. While fish passage may be possible under some flow conditions, culverts have not been designed for fish passage. Looking ahead, Figure 5-1 synthesizes the assessment of the habitat values of each reach of creek. In the short-term, elimination of barriers and/or obstructions may result in limited access to potential habitat.

For the 50-year vision, on the other hand, there may be opportunities to develop and implement a comprehensive and integrated program for acquiring additional riparian corridor width and recreating physical habitat in conjunction with watercourse stabilization and culvert upgrading.

Watercourse Stabilization and Habitat Enhancement

Looking ahead, Chapter 5 includes a discussion on the effectiveness of habitat enhancement programs in an urban environment. Simply put, their ultimate effectiveness is subject to achieving EIA-reduction objectives that, in turn, mitigate the *changes in hydrology* that trigger watercourse wear-and-tear.

Table 4.2
Stoney Creek Culvert Inventory and Assessment Summary

Culvert No.	Watercourse	Location	Photo No.	Type	Material	Dia./Width (mm)	Height (mm)	Length (m)	Headwall	Headwall Height (m)	Individual PipeFlow Capacity (m^3/s)	Total Flow Capacity* (m^3/s)	Q100** Unrestricted (m^3/s)	Q100** Restricted (m^3/s)	Q100 Restricted Passed	XPSWMM Link I.D.	Maintain Creek Line/Grade	Bridges Channel	Inlet Structure	Passes Small Debris	Debris Interceptor	Scour Protection	Safe Overflow Route	Equipment Access	Environmental Issues	Overall Assessment***	Comments
1a	Stoney Creek (Main)	Railway Crossing	A9 - A13	circ	cmp	1500	n/a	30	none	n/a	3.2																
1b	Stoney Creek (Main)	Railway Crossing	A9 - A13	circ	conc	1850	n/a	30	none	n/a	6.0	9.2	32.9	25.4	N	R2	Y	N	N	Y	N	Y	N	Y	Y	P	Upgrade culverts
2a	Stoney Creek (Main)	Government Street	A15 - A16	circ	conc	1500	n/a	26	with square edge	3	4.5																
2b	Stoney Creek (Main)	Government Street	A15 - A16	circ	conc	1800	n/a	26	with beveled edge	3	6.2	10.7	32.9	25.4	N	R2	Y	N	Y	Y	N	Y	N	Y	Y	P	Upgrade culverts
3a	Stoney Creek (Main)	Lougheed Highway	A22 - A23	circ	conc	1200	n/a	30	with square edge	2.5	3.3																
3b	Stoney Creek (Main)	Lougheed Highway	A22 - A23	circ	conc	1200	n/a	30	with projecting	2.5	3.5																
3c	Stoney Creek (Main)	Lougheed Highway	A22 - A23	circ	conc	1800	n/a	30	with projecting	2.5	6.0	12.8	32.9	25.4	N	R2	Y	N	Y	Y	Y	N	N	Y	N	P	Upgrade culverts
4	Stoney Creek (Main)	North Road Crossing	n/a	box	conc	1400	1200	16	assumed projecting	n/a	2.7	2.7	7.3	5.8	N	R6-3	Y	N	N	Y	N	Y	N			P	Upgrade culverts
5	Stoney Creek (Main)	Chapman Road	D9 and D12	circ	conc	1300	n/a	50	with square edge and wing walls at 45°	1.5	2.3	2.3	4.3	3.1	N	R8-1	Y	N	N	Y	N	Y	N	Y	N	P	Provide debris Interceptor and emergency overland flow route.
6	Stoney Creek (Main)	Ailsa Avenue	D19	circ - inlet arch - outl	conc cmp	1400 1400	n/a 1000	26	with square edge	2	2.8	2.8	2.5	2.2	Y	R8-2	Y	N	N	Y	Y	Y	Y	Y	N	G	Provide Inlet Structure and fish passage.
7	Tributary 1	Gaglardi Way	E7	circ inlet	conc	870	n/a	n/a	none	n/a	0.9	0.9	0.8	0.8	Y	R9-4	N	N	Y	Y	Y	Y	N	Y	N	G	Tributary 1 pipe downstream
8	Tributary 1	Forest Grove Drive	E13 and E14	circ	conc	1000	n/a	35	with square edge	2	1.2	1.2	0.8	0.8	Y	R9-3	Y	N	Y	N	Y	Y	Y	Y	N	G	Provide emergency overflow reentry point to creek
9	Tributary 1	Cinamon Dr /Pipeline ROW	E17 and E18	circ	pvc	800	n/a	4	with projecting	1	0.8	0.8	0.8	0.8	Y	R9-3	Y	N	N	Y	N	Y	Y	Y	N	G	Pathway culvert throug pipeline right of way
10	Tributary 1	Pineridge Drive (Private Driveway)	E19	circ	conc	1000	n/a	16	with projecting	1.8	1.3	1.3	0.8	0.8	Y	R9-3	Y	N	Y	N	N	Y	N	Y	N	G	Remove riprap stone build up at inlet.
11	Tributary 1	Driveway to Pump Station	E23	circ	cmp	450	n/a	~30	with projecting	n/a	0.2	0.2	0.8	0.8	N	R9-4	Y	N	N	Y	N	Y	Y	Y	N	G	No action
12	Tributary 2	Townhomes at Beaver Brook	F8	arch	cmp	1500	900	4	with 0° wing wall flares	1.2	1.5	1.5	1.7	1.7	N	R10-2	Y	Y	N	Y	N	Y	Y	Y	N	G	Provide debris interceptor
13	Tributary 2	Gaglardi Way - Piped Creek S	G2	circ	conc	1050	n/a	~60	with projecting	n/a	1.6	1.6	1.7	1.7	N	20002	N	N	N	Y	N	Y	N	Y	N	G	Clear vegetation over growth from inlet
14	Tributary 2	Bwtn Gaglardi & Forest Grove	G1	circ	cmp	950	n/a	~18	none	n/a	1.0	1.0	1.5	1.5	N	R10-3	Y	N	N	N	N	N	N	Y	N	P	Culvert is partially collapsed. Upgrade culvert.
15	Tributary 2	Forest Grove Dr (South)	F23 and F25	arch	cmp	1250	800	~20	flush to headwall	1.6	0.8	0.8	1.5	1.5	N	10-3, Area 3	Y	N	Y	Y	Y	Y	Y	Y	N	G	Culvert does not bridge channel.
16	Tributary 2	Forest Grove Dr (North)	F14 and F12	arch	cmp	1000	600	n/a	flush to headwall	1	0.6	0.6	1.3	1.3	N	R10-4	y	N	Y	Y	Y	Y	Y	Y	N	G	Cuvert does not bridge channel.
17	Tributary 2	Ash Grove Cresent	F16 and F20	circ	cmp	800	n/a	~30	with square edge	1.2	0.7	0.7	0.8	0.8	N	R10-5	Y	N	Y	Y	Y	Y	Y	Y	N	G	Culvert does not bridge channel.
18	Tributary 2	Gaglardi (North)	F21, F22	circ	cmp	700	n/a	>60	with square edge	1.5	0.5	0.5	0.6	0.6	N	R10-6	Y	N	N	Y	N	N	N	Y	N	G	Provide scour protection at outlet.
19	Tributary 3	Gaglardi Way	G25	box	conc	2000	1500	n/a	riprap - projecting	1.5	5.2	5.2	6.8	4.4	Y	R11-2	Y	Y	Y	Y	Y	Y	Y	Y	Y	G	Passed Q100 with headwater = 2 m
20	Tributary 3	Foot Path crossing within Gaglardi Way east ditch, north of culvert no. 23	H3, H5	circ	conc	1000	n/a	~3	none	n/a	1.3	1.3	3.7	3.7	N	R12	Y	Y	N	Y	N	Y	Y	Y	Y	G	Flows exceeding culvert maintained within ditch.
21a	Tributary 3	Ash Grove Cresent (South)	H11, H13	arch	conc	1300	900	n/a	with groove	1	1.5																
21b	Tributary 3	Ash Grove Cresent (South)	H11, H13	arch	conc	1300	900	n/a	with groove	1	1.5	3.0	6.1	3.7	N	R11-3	Y	N	Y	Y	N	Y	Y	Y	N	G	Provide debris interceptor
22																											
23	Tributary 3	Ash Grove Cresent (North)	H19, H20	arch	cmp	2000	1500	~30	with square edge	2	4.0	4.0	6.1	3.6	Y	R11-4	Y	N	Y	Y	Y	Y	Y	Y	N	G	Provide emergency overflow reentry point to creek

Note:
* - Hw=Diameter
** - Existing Land Use

*** E - Excelle - Passes all criteria
G - Good - Passes all criteria assuming HW = 1 to 2m
F- Fair - Passes most criteria - flag for upgrades in long term
P-Poor - Structure fails criteria and should be replaced in near future

Y -Passes criteria
N -Does not pass criteria

Peak flow summary of the 2,5,10,25, &100 included in Appendix C

4.6 Summary of Findings

Framework for Flood Risk Management

Based on the information presented in the foregoing sections, key findings are highlighted below:

1. The Main Stem of Stoney Creek has been noticeably subjected to erosion for about one-quarter of its length (i.e. the reaches between Beaverbrook and Broadway).
2. The availability of streamflow records for the GVRD station at Government Road has enabled validation of the rainfall-runoff simulation model.
3. The validated model has facilitated a reliable simulation of watershed response to the 100-Year Design Storm.
4. The majority of the 18 existing culvert installations are rated as 'high risk' in terms of vulnerability to blockage.
5. The floodway that defines the Main Stem can contain Q_{100}.
6. The network of contributory storm sewers typically is adequately sized to convey Q_{10}.

Major flood events are infrequent, and typically occur near the end of a period of prolonged wet weather. The objective of *flood risk management* is to protect property by ensuring that the 'design flood' (i.e. Q_{100}) can be contained. Regardless of what measures may be implemented for *environmental risk management*, the channel system and culvert/bridge installations must have adequate hydraulic capacity to safely route Q_{100} to the Brunette River.

Total versus Effective Impervious Area

TIA (total impervious area) is the 'intuitive' definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt and buildings. Hydrologically, this definition is incomplete for two reasons:

- Ignores nominally 'pervious' surfaces that are so low in permeability that the rates of runoff from them are similar or indistinguishable from pavement.
- Includes some paved surfaces that may contribute nothing to the storm-runoff response of the downstream system.

The second of these limitations is formally addressed through the concept of *effective impervious area (EIA)*, defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream)system. Thus, any part of the TIA that drains onto pervious ground is excluded from the measurement of EIA. The overall TIA for the Stoney Creek watershed is 29%. Once the computer model is calibrated, it will be possible to establish a precise value for EIA, and to monitor changes.

CHAPTER 5

RESULTS OF AQUATIC HABITAT ASSESSMENT

5.0 RESULTS OF AQUATIC HABITAT ASSESSMENT

5.1 Introduction

A Perspective

This part of the study could be viewed as the bridge between the two engineering components (i.e. storm runoff control, and runoff quality control). It identifies the natural resources to be protected by a management strategy that mitigates *changes in hydrology* and *water pollution.*

A Starting Point for Stormwater Management

To select an appropriate management strategy, it is necessary to identify the threats to those resources to be protected, and the alternative management strategies. This chapter comprises five sections that provide a starting point for development of the 'environmental component' of an integrated strategy by assessing the environmental resource values of the Stoney Creek system.

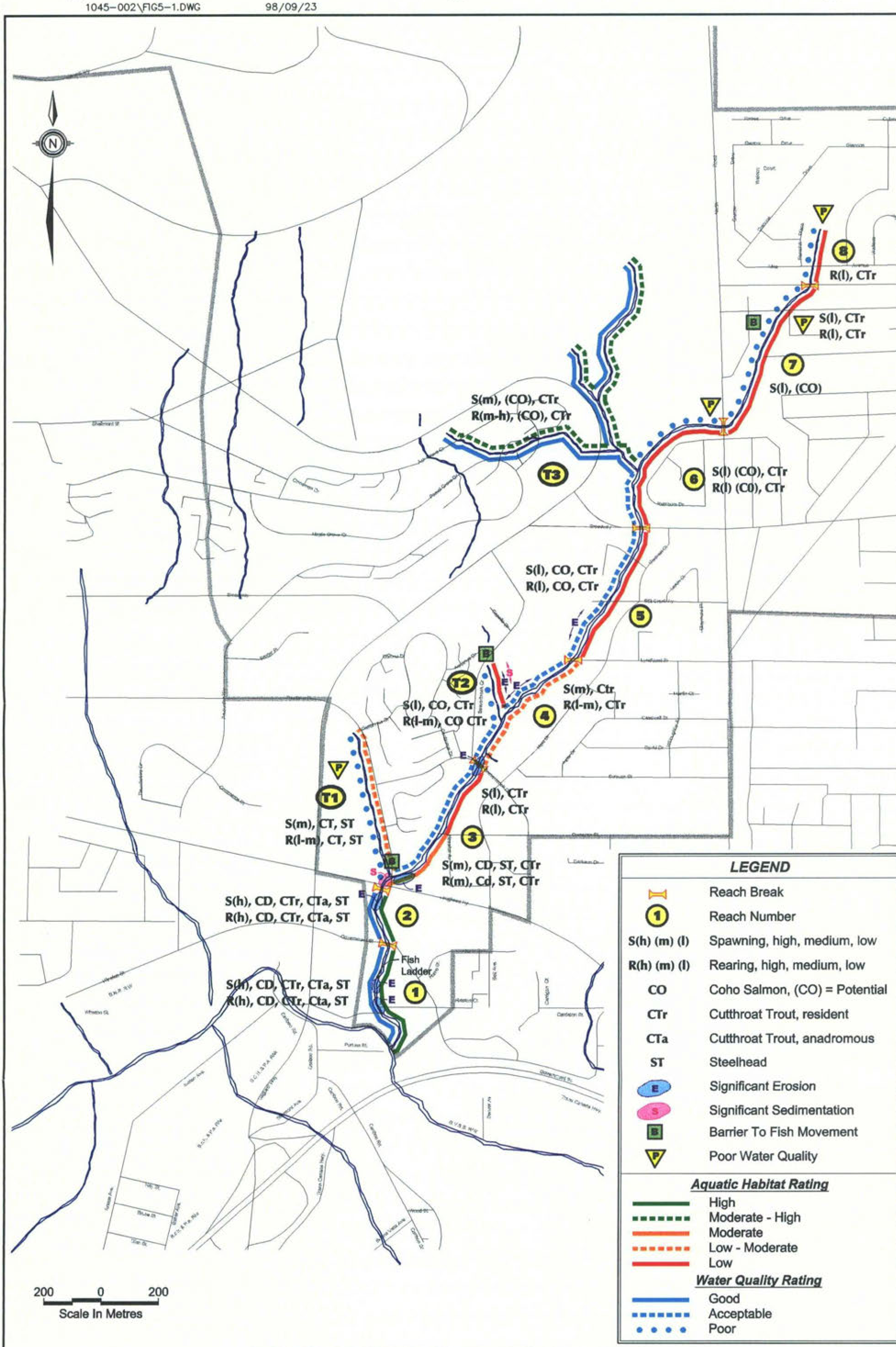
- **Work Program Objectives:** Five objectives define the framework for a comprehensive approach to information gathering and assessment.
- **Ecosystem Overview:** While there is a heavy emphasis on 'fish issues' in this study, fish are but one element of the natural resources of Stoney Creek. This section provides highlights *structural features* and *functional aspects* of the ecosystem.
- **Critical Environmental Issues:** Six categories are identified for documenting information on fish habitat resources. These provide the basis for a set of reach-by-reach tabular summaries that are presented in Appendix F.
- **Habitat Enhancement Opportunities:** Lists reach-by-reach the enhancement opportunities that have identified in previous bio-inventories and validated/revisited through the Expert Workshop process.
- **Planning Implications:** Begins to develop a picture of the environmental protection considerations that shape selection of the elements of a stormwater management plan for 'holding the line' and 'improving conditions' over time.

The presentation of information is short-form, with the objective of highlighting critical findings that impact on the decision process. The emphasis is on providing a reach-by-reach overview that facilitates an understanding of fisheries issues.

Identification of Stream Reaches

The Stoney Creek main stem comprises eight reaches as previously described in Chapter 4, and as shown on Figure 5-1. The channel system includes three tributaries on the west side.

1045-002\FIG5-1.DWG 98/09/23



KWL-CH2M CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

R.U. KISTRITZ CONSULTANTS LTD.

RESULTS OF AQUATIC HABITAT ASSESSMENT

FIGURE 5-1

5.2 Objectives of Aquatic Habitat and Fisheries Program

Framework for Information Gathering and Assessment

The following objectives have defined the framework for a comprehensive approach to information gathering and assessment:

- **Objective #1:** Review all existing biophysical information available on the Stoney Creek system.
- **Objective #2:** Fill any critical information gaps with field inspections of specific locations or Reaches.
- **Objective #3:** Develop a map that highlights habitat concerns related to sedimentation and erosion, barriers to fish movement, and pollution point sources.
- **Objective #4:** Organize an *Expert Workshop* for a select group of individuals with practical 'hands-on' experience on the Stoney Creek system to refine the watercourse map and build consensus on habitat values and threats.
- **Objective #5:** Analyze and integrate the habitat and fisheries constraints with the hydrotechnical requirements and land use into a map that designates the Stoney Creek system into reaches for stormwater management planning.

The key to successfully fulfilling all five objectives has been the proactive involvement of the *Stoney Creek Environment Committee (SCEC)* in the investigative process. In fact, the previous work by the SCEC has provided the foundation for the aquatic habitat assessment presented herein.

Approach to the Expert Workshop

The purpose of the workshop with the SCEC in May 1998 was to validate/update previously documented biophysical information on the Stoney Creek system. The input from the workshop participants is compiled in Appendix D. For each reach, information from these three sources has been tabulated:

- *Biophysical Survey and Habitat Enhancement of Stoney Creek,* a report prepared by Global Fisheries Consultants Ltd in 1995 for the Ministry of Transportation and Highways.
- *A Summary of the Biophysical and Ecological Studies of Stoney Creek,* a report prepared in 1997 by K. Goody for the SCEC.
- *Documentation of Aquatic Habitat Knowledge,* a summary of the workshop results.

Appendix F provides a concise summary of information in an easy-to-follow tabular format.

5.3 Overview of Stoney Creek Ecosystem

The Stoney Creek sub-watershed supports an ecosystem that is vital to the fish and wildlife resources of the entire Brunette watershed. A significant area of the upper watershed of Stoney Creek is dominated by the dense hardwood-coniferous forest that covers much of Burnaby Mountain. The lower reach of Stoney Creek near its confluence with the Burnette River supports a rich and diverse riparian swampland and small wetlands. These remaining densely vegetated areas provide an important riparian corridor that effectively protects and conserves many of the aquatic components and functions that are vital to a healthy stream ecosystem.

The natural riparian corridor of Stoney Creek is important as a wildlife refuge and corridor for the indigenous urban wildlife species. Because of the relatively large size of the remaining forested area in the watershed, the Stoney Creek ecosystem also serves an important role in preserving species and genetic diversity. For example, a total of 79 different bird species have recently been recorded by the Stoney Creek Environmental Committee (Goody 1997). Four of those species are on the Conservation Data Centre's (CDC) rare elements tracking list. Further wildlife observations and studies will likely reveal amphibian, reptile, and small mammal species that may also be on the CDC's rare elements tracking lists.

The most significant aquatic components of the Stoney Creek ecosystem can be found among the fish fauna. Reaches (1 and 2) below the fish ladder support spawning and rearing populations of coho and steelhead, as well as resident and sea-run cutthroat trout. The presence of steelhead and anadromous cutthroat trout is particularly significant because of their rare occurrence in urban streams. Construction of the fish ladder in 1980 (improved in 1997) provided access for coho salmon to the upper Reaches as far as Reach 5 (Broadway) and potentially up to Reach 7 (Tributary #3 and to North Road). Further information on Stoney Creek's fishery resources are available from the SCEC, the Sapperton Fish and Game Club, and from FISS and watershed databases of the DFO and MELP.

The physical and biochemical processes of the Stoney Creek ecosystem must also be appreciated in terms of their significance to stormwater management. The rich and diverse flora and fauna supported by the Stoney Creek ecosystem enhances the natural assimilative capacity of the stream to absorb and break down many different kinds of pollutants. Healthy and diverse populations of aquatic bacteria, plants, and invertebrates play a major role in the assimilation and metabolism of excess nutrients, and organic pollutants.

Heavy metals and other pollutants associated with suspended solids will be removed in natural sinks such as wetland and other low velocity areas. Water temperature will be reduced in areas shaded by the dense riparian vegetation canopy. Areas of turbulent flow will oxygenate water. And finally, the input of groundwater will dilute and therefore reduce the concentration of surface water contaminants.

5.4 Identification of Critical Environmental Issues

A number of critical environmental issues need to be addressed in order to fully integrate the environmental components and functions into the stormwater management plan. The first issue addresses the location of the most valuable and sensitive salmon and trout spawning and rearing habitat that needs to be protected.

The next issues relate to various limits and constraints of the ecosystem such as erosion, sedimentation, barriers to fish movement, and point source pollution. These limits and constraints need to be incorporated into the stormwater management plan or they need to be resolved as enhancement opportunities. Key points to note are:

- **Spawning and Rearing Habitat**: Steelhead salmon and sea-run cutthroat are known to spawn in the lower reaches below the fish ladder. Some steelhead spawning has also been observed above the fish ladder in Tributary #1 and Reach 3. Coho salmon are know to spawn in the main stem as far as the upper part of Reach 5 near Boundary, and in Tributary #2.

  Resident cutthroat spawning occurs in various locations throughout the stream system. The quality of trout and salmon rearing essentially mirrors that of spawning habitat for those species. However, cutthroat trout juveniles are distributed throughout the system and coho salmon juveniles are found throughout the system downstream of their natal habitats.

- **Erosion**: Erosion sites are deemed to be significant if they exceed the natural dynamic erosion process, and are chronic in nature. In Reach 1 there is a significant site just below the fish ladder and some 200 metres further downstream. There are problem sites both above and below the Lougheed culverts. Other sites include the crossing at Beaverbrook, much of Tributary #1, and several sections of Reaches 4 and 5.
- **Sedimentation**: One of the most significant sedimentation sites is associated with the area around the upstream end of the Lougheed culverts.
- **Barriers to Fish Movement**: All three tributaries end at culverts that are impassable to fish. The main stem becomes impassable to migrating trout and salmon in Reach 7 due to the excessive gradient between Thompson and Chapman Avenues.
- **Point Source Pollution**: Tributaries #1 and #2 have known point source pollution from storm sewers that emit excessive levels of suspended sediment or soap. The upper reaches of the main stem receive high levels of nutrients.

All of the above criteria are combined in a reach-by-reach, aquatic habitat rating of high, medium, and low values. These ratings reflect professional judgement. The criteria and the rating categories are shown on the aquatic habitat map, which are presented as Figure 5-1.

TABLE 5-1: Identification of Habitat Enhancement Opportunities

Reach	1995 Report by Global Fisheries	1997 Report by SCEC	May 1998 Expert Workshop
1. Brunette River to Government	• no recommendation	• no recommendation	• install fencing around RV park • maintain small oxbow
2. Government to Loughheed	• no recommendation	• no recommendation	• improve existing side-channel compensatory site
Tributary # 1	• no recommendation	• address erosion • storm drain marking	• lower sanitary sewer below creek bed • incorporate meandering and complexing with LWD and pools • widen creek bed in conjunction with potential acquisition of BNR property • provide biofiltration for storm sewer effluent • augment base flow during low flow season
3. Lougheed to Beaverbrook	• no recommendations	• placement of LWD • side channels	• add baffles inside Lougheed culvert • correct erosion of east side tributary upstream of Lougheed • create off-channel habitat and wetland biofiltration • restore riparian vegetation along GVRD access road
4. Beaverbrook to Lyndhurst	• no recommendation	• stabilize clay banks	• fix major bends that have bank erosion • decommission trail
Tributary # 2	• no recommendation	• relocate path • streamside planting • naturalize u/s channel	• improve drainage on school playing field • create off-channel habitat on east side of Stoney Creek as per proposed habitat compensation
5. Lyndhurst to Boardway	• no recommendation	• decr. ROW width • streambank planting • more instream hab. • off-channel habitat • stabilize banks	• stabilize west bank to arrest downslope movement of soil • replace existing weir (note: it is understood that this will be done by GVRD)
Tributary # 3 (lower reach)	• no recommendation	• no recommendation	• address clay bank erosion
Tributary # 3a (south branch)	• replace hanging culvert at Gaglardi	• no recommendation	• note: culvert has been replaced
Tributary # 3b (north branch)	• construct pools • repair bike path • remove car wreck	• no recommendation	• Resolve the problem of trail usage by mountain bikers (note: this is being addressed through Burnaby Mountain Management Plan)
6. Broadway to North Rd.	• plant trees along bank	• public education and signage	• fence access road to discourage trash tipping • create route into park for spillway & off-channel habitat • resolve concerns re two rock weirs (note: this is being addressed by GVRD)
7. North Rd. to Chapman	• no recommendation	• no recommendations	• no recommendations
8. Chapman to Glenayre Pk	• no recommendations	• no recommendations	• no recommendations

5.5 Opportunities for Riparian and Habitat Enhancement

A Perspective

Some habitat enhancement opportunities were identified during the field reconnaissance. Additional enhancement opportunities were compiled during the Expert Workshop. Further enhancement plans have been developed in connection with the environmental assessment for the Secondary School project.

Some of those habitat enhancement plans remain under review by the federal and provincial environmental agencies. It is beyond the scope of this study to develop a detailed habitat enhancement prescription for Stoney Creek that would satisfy all of the current needs and jurisdictions. Instead we include a tabular summary of the enhancement opportunities that were identified by workshop participants.

Starting Point for Habitat Enhancement Program

Table 5-1 organizes the suggested enhancement opportunities according to the various reach locations. Also included are enhancement opportunities that have been identified in previous studies by Global Fisheries (1995) and the SCEC (1997).

Table 5-1 identifies a set of site-specific action items, and is supported by the set of detailed tables included as Appendix F. The action items reflect local observations and experience. They also provide a possible starting point for development of a comprehensive *Habitat Enhancement Program* in conjunction with watercourse stabilization.

The objective of such a program would be to systematically improve aquatic habitat conditions in the channel system. Development of a *Habitat Enhancement Program* is beyond the scope of this study.

Preliminary Assessment of Action Items

The action items for in-stream work are generally small-scale, and do not merit bringing forward as recommendations within the context of a macro-planning study. Their real significance is that they highlight the need to mitigate the *changes in hydrology* that are noticeably impacting on the 'environmental health' of stream corridors.

Further to the above, it follows that the long-term effectiveness of in-stream habitat restoration and enhancement measures will ultimately depend on 'watershed restoration.' This observation reflects the paradigm-shift that is taking place at the management level within the environmental agencies.

5.6 Implications for Watershed Planning Process

Identification of Best Habitat Values

Of the four objectives identified in Section 5.1, the first four lay the ground for the fifth objective, which is to designate the critical reaches of Stoney Creek that drive the stormwater management strategy. Figure 5-1 is the culmination of this process and is a key deliverable because it presents a picture that enables these defining conclusions to be drawn with respect to habitat value:

- **Highest Value Reach:** This is the section between the Lougheed Highway and the confluence with the Brunette River.
- **Next Best Reach:** This is Tributary #3, both the north and south branches.

Above the Lougheed Highway, the aquatic habitat in the main stem is for the most part rated as being 'low' in value. The sections immediately upstream and downstream of the confluence with Tributary #2 are rated as being 'low to moderate' in value. Tributary #1 also has a 'low to moderate' rating.

Application of Findings

Based on the foregoing findings, the stormwater management strategy needs to protect the two best sections of creek from further *changes in hydrology*; and enable conditions to be improved in the main stem above Lougheed.

The riparian corridor along the main stem between Lougheed and Broadway has been compromised by GVRD sewer and trail construction. Hence, a comprehensive solution would include a revegetation program, reallignment of the trail system to be 'fish-friendly', and restoration of in-stream habitat.

For the two 'best sections' of creek (as identified above), it is noteworthy that the items listed in Table 5-1 are 'off-site' in nature. This underscores the conclusion that a stormwater management strategy needs to be watershed-based to protect the best in-stream resources.

Inter-Relationship of Limiting Factors

Chapter 2 introduced the four factors limiting the ecological values of urban creeks. These factors provide a 'roadmap' for development of an integrated stormwater management strategy. Significantly, the consequences of *changes in hydrology* progressively manifest themselves in the disturbance of riparian and aquatic habitat, and in the deterioration of water quality.

Effectiveness of Habitat Enhancement Programs in Urban Streams

Guidelines for Community Involvement Initiatives

A recent review (by the project team) of published literature in the USA did not identify a single documented study that has demonstrated an increase in fish production on a watershed basis as a result of habitat enhancement. In contrast, there are numerous anecdotal cases of habitat enhancement projects that were populated by fish after completion.

Habitat enhancement projects are very popular with citizens because they feel they are making a positive contribution to the environment. This situation offers some guidance for management programs, generally as follows:

- Habitat enhancement efforts should be considered primarily an educational activity.
- The first priority for habitat enhancement should be identification and removal of barriers and/or obstructions to fish migration in designated fisheries creeks. This simple action could significantly increase fish production in some areas.
- The second priority should be planting vegetation along riparian corridors that will provide shade to streams. This can provide shade to lower water temperatures, provide insects that are a food source for fish, and stabilize stream banks.

Until *changes in hydrology* in urban systems are regulated, there is little benefit in instream habitat enhancement in areas identified as 'low' to 'moderate' on Figure 5-1.

Protection of Streams from Various Threats

The purpose of this sub-section is to capture the essence of a presentation by Otto Langer (of the Department of Fisheries & Oceans) on November 3rd 1998 at a BCWWA seminar titled *Classification of Streams and Watersheds as a Tool for Stormwater Management*. Langer introduced the following continuum to conceptualize what is being done, and how effectively it is being done, to protect streams from the impacts of urbanization:

Development of Watershed →	Development Within FSZ (Fisheries Sensitive Zone) →	Work Within Stream
Largely Ignored →	Poorly Done →	Most Addressed

The message from his presentation was "restore the watershed first, then the stream." He advocated an ecosystem approach that places a priority on maintaining the upper reaches of watersheds in order to protect downstream resources.

Monitoring the Environmental Health of Stream Corridors

Although the Main Stem of Stoney Creek has been noticeably subjected to erosion for about one-quarter of its length, the watershed supports an ecosystem that is vital to the fish and wildlife resources of the Brunette Basin. Specifically, the Stoney Creek ecosystem supports spawning and rearing populations of coho and steehead trout, as well as resident and sea-run cutthroat trout. The presence of steelhead and anadromous cutthroat trout is particularly significant because of their rare occurrence in urban streams.

The foregoing findings underscore the need for an environmental monitoring program that is based on parameters/indicators that accurately represent the environmental state of the surface drainage function and the ecological functions of receiving water bodies. Given this starting point, a framework for action is summarized as follows:

- Given that changes in hydrology and physical habitat are the primary impacts of urbanization on stream corridor ecology, a program that is based on physical habitat and biological indicators would have the greatest benefit.
- The purpose of the program would be to warn whether or not human actions are impacting on streams and riparian habitat, and locate/identify sources of degradation.
- The monitoring program proposed for Stoney Creek is keyed to an ambient biological assessment methodology known as the *Benthic Index of Biotic Integrity (B-IBI).*
- This methodology could complement or augment the ongoing biological monitoring work by the SCEC that is based on the Advanced Stream Habitat Survey from the *Streamkeepers Manual.*
- The B-IBI methodology consistently correlates well with urbanization, is sensitive to slight change, and is gaining recognition in the Pacific Northwest as a result of the efforts of Dr. James Karr of the University of Washington.
- An *Integrated Monitoring Program* would comprise ambient biological monitoring, continuous rainfall and streamflow recording, and some chemical and habitat measurements.

Ambient biological assessments directly measure the condition of the resource at risk, detect problems that other methods may miss or underestimate, and provide a systematic process for measuring progress resulting from the implementation of water quality programs.

5.7 A Look Ahead

Environmental Component of an Integrated Management Strategy

Protecting the natural environment for watercourse typically focuses on protection of fish and fish habitat. If abundant and diverse fish populations are present, the physical environment has been protected. Protection of fish populations requires protection of the hydrology, buffer strips along stream corridors with natural vegetation, physical habitat within the stream, and water quality.

Developing a long-term strategy for habitat protection involves identifying key principles for a stewardship approach to stream corridor management. A critical consideration is having an understanding of how changes in land use progressively impact the ecology of a stream corridor. The previously introduced Figure 2-3 illustrates the consequences for the environmental health of a stream corridor.

The challenge in developing a long-term strategy is being able to integrate two lines of thinking....because the strategy must reflect a combination of existing resource values and future land use scenarios.

Assessment of What is Achievable

Achieving the management objectives for the Stoney Creek watershed is based on first analyzing the four 'limiting factors' as defined in Chapter 2 (i.e changes in hydrology, loss of riparian corridors, loss of physical habitat, and water quality degradation), and then identifying appropriate strategies in response.

Mitigating the *changes in hydrology* would enable stabilization of the rate of watercourse erosion so that fish habitat would be protected. Mitigating those changes would also reduce sedimentation, and thereby protect the beneficial uses of the Stoney Creek system. These issues are addressed in Chapter 7.

Identification of Future Opportunities

It would be desirable to identify opportunities for integration of proposed stormwater and aquatic habitat improvements with:

- Greenway and green space planning in the watershed.
- Official community plans, development permits, zoning and development approval processes in the watershed.
- Urban design issues such as amount of impervious surface, streamside setbacks and use of yards adjacent to watercourses, and relationship of proposed watercourse improvements to development potential, aesthetics and land values.

The focus would be on identifying implementation tools administered by planning or parks departments that may complement available engineering tools.

CHAPTER 6

RESULTS OF RUNOFF QUALITY MONITORING

6.0 RESULTS OF RUNOFF QUALITY MONITORING

6.1 Background

Overview of Study Components

Chapter 5 noted that the aquatic habitat assessment could be viewed as the bridge between the two engineering components (i.e. storm runoff control, and runoff quality control). Given this linkage, the runoff quality part of the study comprises two distinct sub-components as summarized below:

- **Baseline Quality:** Carry out a water quality-sampling program to characterize existing conditions.
- **Environmental Priorities:** Develop guidelines for future in-stream environmental protection and enhancement programs.

The results of the quality assessment provide a basis for selection of BMPs for urban runoff improvement. To select appropriate BMPs, it is first necessary to identify the resources being protected, the threats to those resources, and the alternative BMPs.

Assessment of Baseline Water Quality

The 3-step process for assessment of baseline water quality is summarized below:

- **Step #1:** Develop a sampling strategy.
- **Step #2:** Implement the sampling program.
- **Step #3:** Analyze the results.

Appendix G includes a copy of the *Briefing Paper on a Proposed Runoff Quality Sampling Program for Stoney Creek Watershed.* (i.e. Step #1). It provides supporting details with respect to the approach and rationale for parameter selection for analysis.

Components of Baseline Monitoring Program

The baseline-monitoring program comprised two distinct component programs that were designed to answer questions such as those summarized below:

- **Baseflow Sampling:** What are the current water quality conditions? How do conditions in the upper watershed compare to those downstream?
- **Stormwater Sampling:** What is the contaminant load associated with stormflow events? What is the relationship between TSS and turbidity?

The monitoring program included a station at Government Road for continuous recording of water level versus turbidity measurements.

6.2 Overview of Monitoring Program

The runoff quality of Stoney Creek was sampled and analyzed to obtain a "snapshot" view of the water quality conditions in Stoney Creek during the study period. Baseflow measurements were taken to gauge the type of longer duration pollution stress that aquatic life might be exposed to. Stormwater measurements were taken to assess the short-duration exposures to high concentrations.

Baseflow Monitoring: Sampling Dates and Parameter Testing

Baseflow samples were manually sampled on May 20th 1998 and June 17th 1998. An upstream sample was taken at Broadway Avenue, a downstream sample at Government Street, and a comparative sample at the Brunette River near Cariboo Road. The water quality parameters tested were as follows:

Parameter	Detection Limit	Parameter	Detection Limit
Total Suspended Solids	1 mg/L	Copper	0.002 mg/L
Nitrate Nitrogen		Managanese	0.001 mg/L
Fecal Coliform Bacteria	1 (FTU)	Zinc	0.005 mg/L
Total Coliform Bacteria	1 (FTU)	Total Extractable Hydrocarbons	1 mg/L
		Chemical Oxygen Demand	20 mg/L

Storm Event Monitoring: Sampler Operation and Parameter Testing

A contnuous water quality monitoring station was set up at Government Road. In addition, stormwater was sampled by an autosampler installed next to the station. The sampler successfully sampled three storm events - May 24th, June 10th, and June 24th, 1998. Details of the station and sampler are provided in Appendix H.

The autosampler was programmed to obtain 24 discrete samples at predetermined times over the course of a storm event. The sampler was triggered when the water level in the creek reached 0.3 metres. The first twelve samples were taken every 15 minutes following the trigger elevation being reached, and the remaining 12 samples followed at 30minute intervals. The 0.3 metre level was high enough to avoid false alarms, but low enough to begin sampling during the first flush of the storm.

Analyses were performed on a flow-proportioned composite sample derived from the group of discrete samples taken over the course of the individual storms. Stormwater samples were analyzed for the same parameters as the baseflow samples with the exception of total extractable hydrocarbons and bacteria, which required special preparation and bottles that were not amenable to the autosampler.

The water quality station continuously monitored water levels, water temperature, and NTU turbidity. The latter measurements were used to develop a relationship between turbidity and total suspended solids. Total suspended solids were analyzed as discrete samples during several storm events.

6.3 Results of Baseflow Monitoring

Comparison With Federal-Provincial Guidelines

Water quality data results are provided in Appendix H. All baseflow water quality results were within acceptable federal-provincial water quality guidelines for the protection of aquatic life. The only exception to this was the concentration of nitrate nitrogen which was four to five times higher than what was measured in the Brunette River.

Comparison of Sampling Stations

Nitrate nitrogen levels were also consistently higher at the upstream site suggesting that there may be sources (e.g., lawn fertilizer) above Broadway Avenue from the urban watershed to the east. The elevated nitrate levels are not unusual and have been reported by Macdonald *et. al.* (1997)[•] for other tributaries in the Brunette River watershed.

Implications of High Nitrate Nitrogen Levels

The long-term implications of high nitrate nitrogen levels may be an increase in spring and summer benthic algal blooms. If there are high levels of nitrite nitrogen, then there may be the additional risk to salmon and trout egg and fry.

The nutrient levels in Stoney Creek should be investigated further in order to determine the exact cause of the elevated levels, and to decide if an abatement or source control program is feasible, or even necessary.

Correlation with Results of Sanitary Sewer Investigation Program

The baseflow sampling also yielded coliform counts that were surprising for a watershed with 29% TIA. However, these random sample results were consistent with the experience of the City of Burnaby in other catchments.

The City's rehabilitation program for sanitary sewers has established that coliform counts in receiving waters can be attributable to sewer exfiltration rather than cross-connections between sanitary and storm pipes. Thus, the program of re-lining/re-grouting/replacing sanitary sewers is reducing infiltration during wet weather periods, and exfiltration during dry weather periods.[•]

• R. Macdonald, K. Hall, and H. Schreier. 1997. Water quality and stormwater contaminants in the Brunette River watershed, British Columbia, 1994/95. Final Report. Westwater Research centre, Institute of Resources and Environment, University of British Columbia.

• D. Soong and M. Pawlowski. 1998. Killing Two Birds with One Stone (An Effective Solution to Infiltration and to Exfiltration in Sewers). Paper Present at 1998 Annual Conference of the BC Water & Waste association held at Whistler, BC.

6.4 Results of Storm Event Monitoring

Storm Event Durations and Responses

Of the three storms that were sampled, the May 24th storm was considerable more intense than were the June 10th and 24th storms. Each storm occurred overnight and lasted approximately 10 hours.

Figures 6-1 through 6-3 present the results of the continuous water quality monitoring program for each of the rainfall events. Each graph shows how turbidity responds quickly to increasing flow, particularly at the beginning of the event. This is characteristic of the 'first-flush' associated with runoff from most urban development. Even though the Stoney Creek Basin is only partially developed, the first flush effects are dramatic.

Comparison with Federal-Provincial Guidelines

Water quality data results are provided in Appendix H. Nitrate nitrogen levels remained high despite the effects of dilution from the storm runoff. This again suggests that there may be an upstream source for this nutrient.

Copper concentrations exceeded the long-term average (0.002 mg/L) and long-term maximum concentration (0.004 mg/L) guidelines for the protection of aquatic life. However, copper concentrations reflect the 'soft water' characteristic of the Lower Mainland.

Assessment of Total Suspended Solids

Total suspended solids of up to 1200 mg/L were measured in the stormwater runoff. However, because of the relatively short duration of exposure to these high levels, fish would not have been at risk. For example, underyearling salmon (the most sensitive life-stage) would have been exposed to levels above 100 mg/L for less than 7 hours, which is well below levels that result in sub-lethal effects (Scott, Kistritz, and Galay 1993)[•].

Relationship Between TSS and Turbidity

A good relationship ($R^2 = 0.949$) was derived for total suspended solids and NTU turbidity as illustrated on Figure 6-4. The regression between suspended solids (SS in mg/L) measured in the labs and turbidity (T in NTU) measured in the field yields the following equation for Stoney Creek: TSS = 1.27 T. This equation can be used to derive suspended solids data from simple turbidity measures.

• Scott, K.J., R.U. Kistritz, and V.J. Galay. 1993. Chilliwack River water quality and fish enhancement opportunities study. Report prepared for B.C Conservation Foundation.

STONEY CREEK WATER QUALITY MONITORING STATION AT GOVERNMENT ST.
Storm Event on May 24/25, 1998

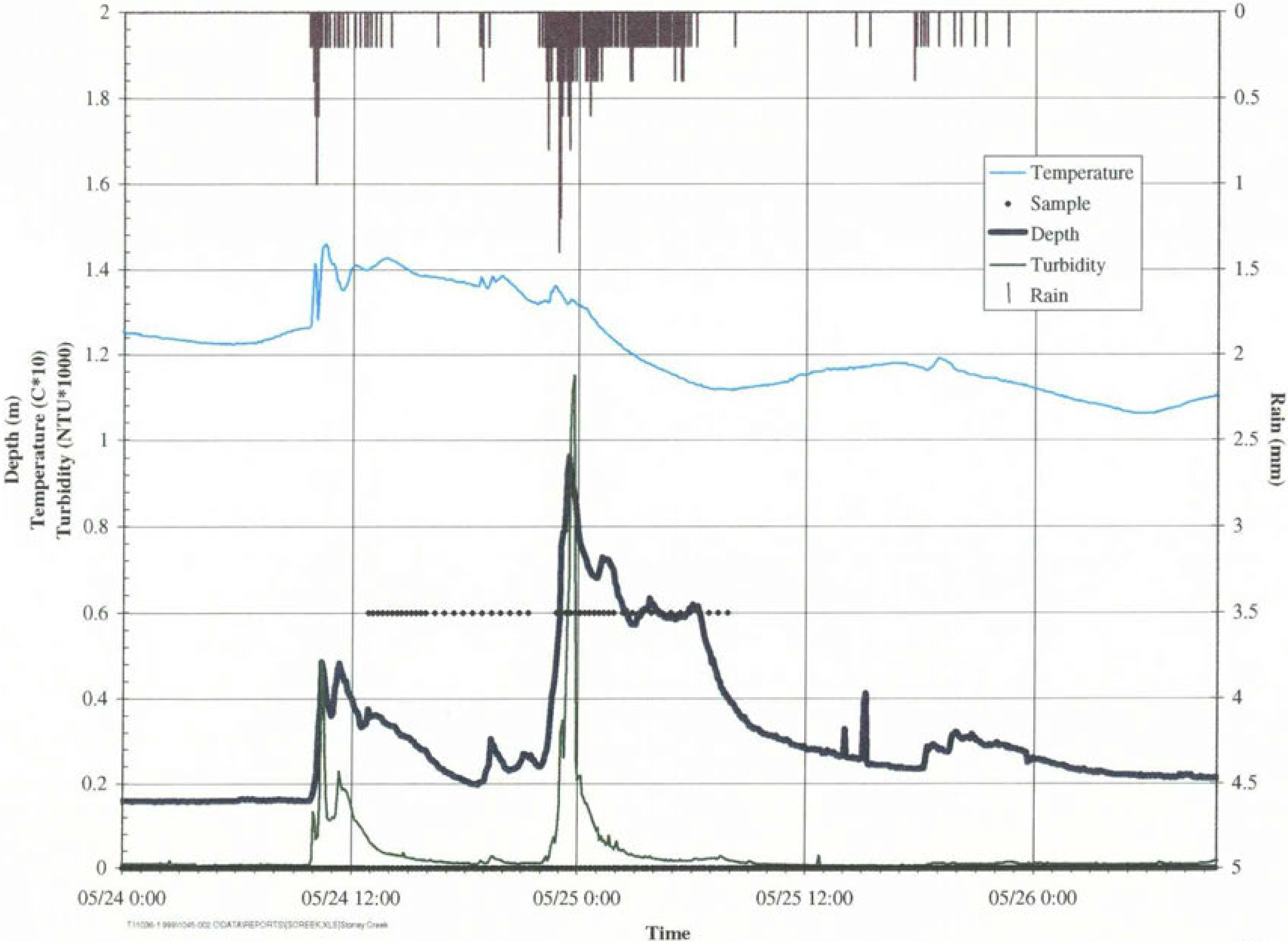


Figure 6-1

STONEY CREEK WATER QUALITY MONITORING STATION AT GOVERNMENT ST.
Storm Event on June 10th, 1998

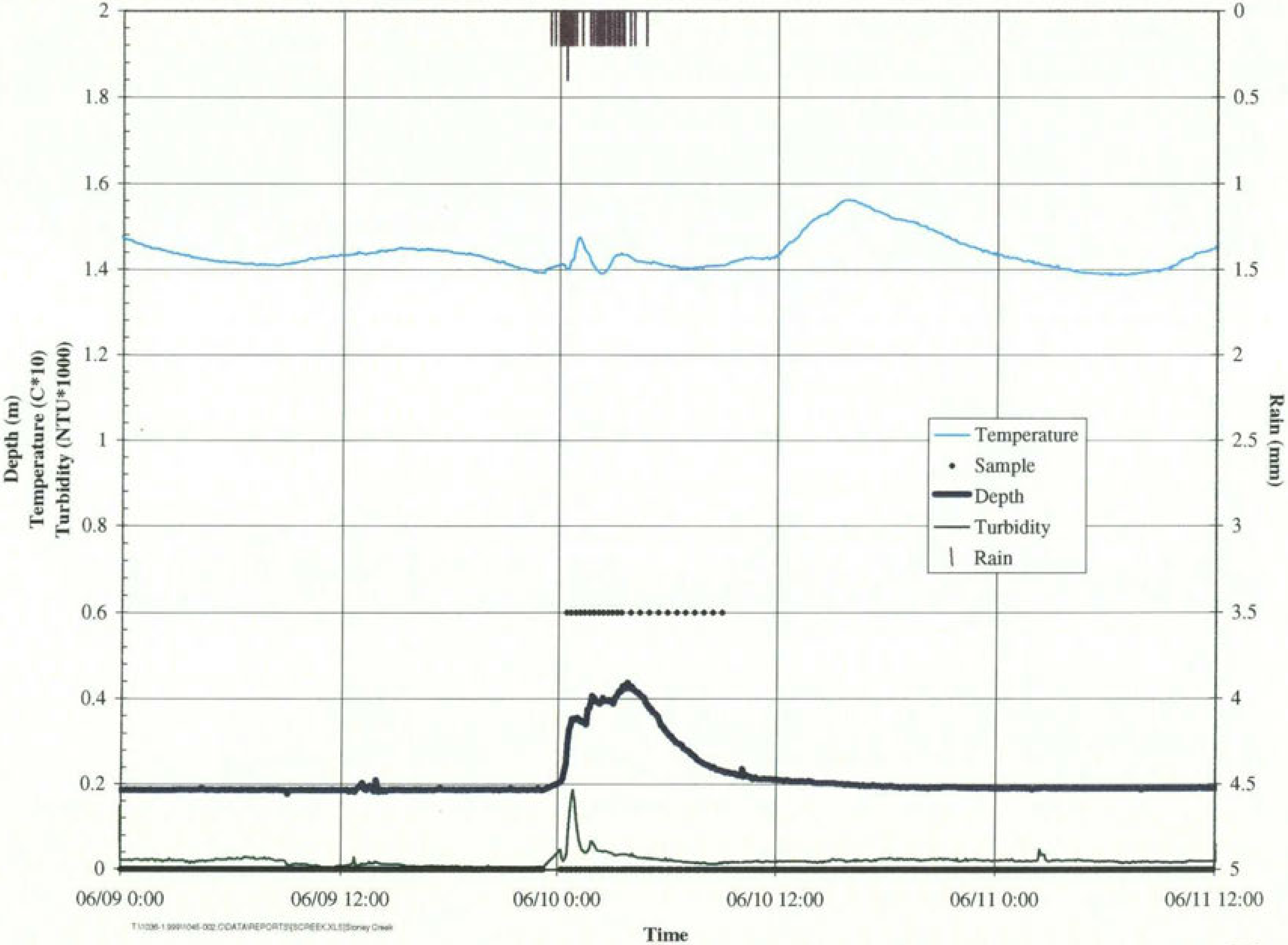


Figure 6-2

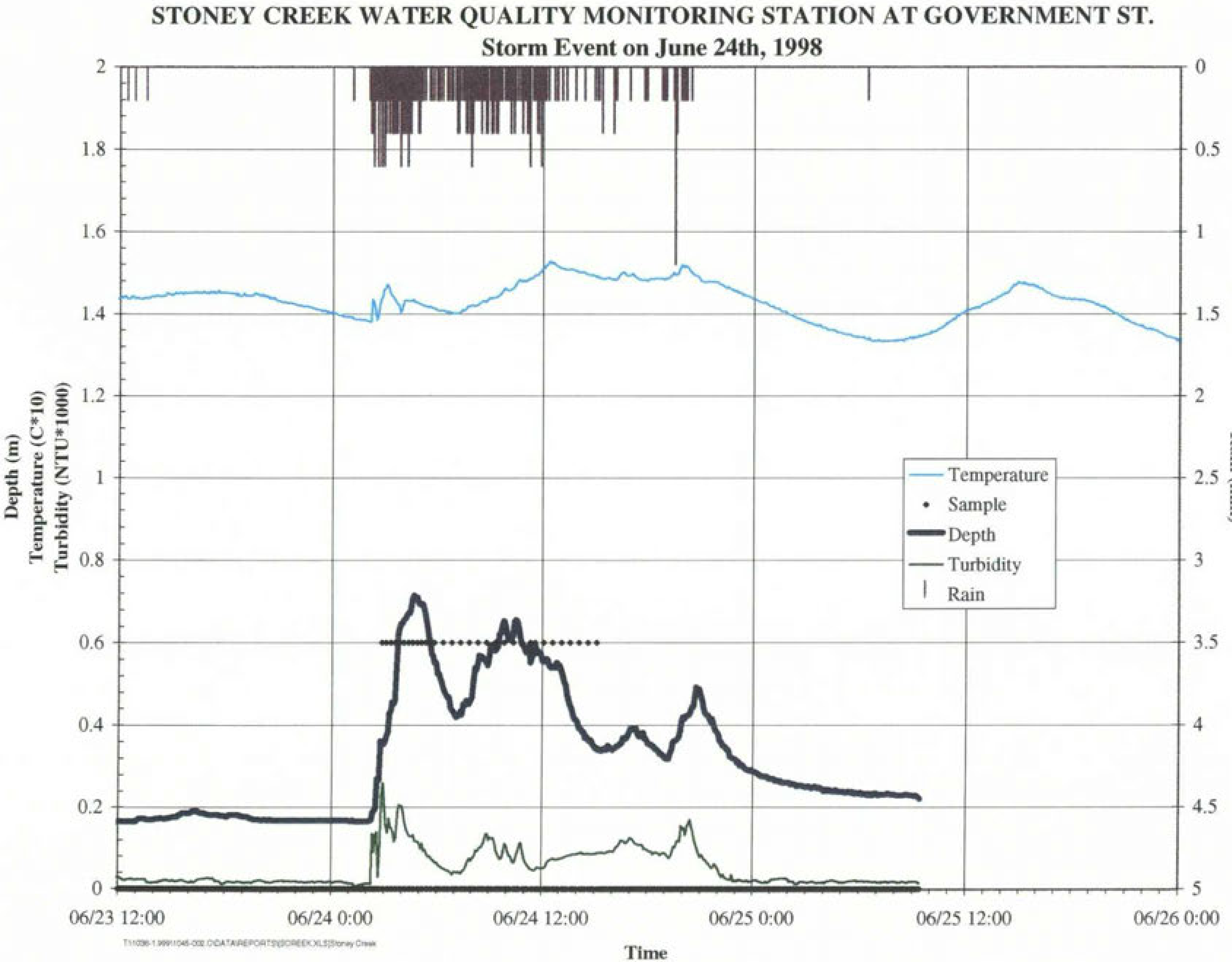

STONEY CREEK WATER QUALITY MONITORING STATION AT GOVERNMENT ST.
Storm Event on June 24th, 1998
Depth (m)
Temperature (C*10)
Turbidity (NTU*1000)
Rain (mm)
Time
Temperature
Sample
Depth
Turbidity
Rain
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
06/23 12:00
06/24 0:00
06/24 12:00
06/25 0:00
06/25 12:00
06/26 0:00

Figure 6-3

STONEY CREEK WATER QUALITY MONITORING STATION AT GOVERNMENT ST.
Turbidity versus Total Suspended Solids (TSS)

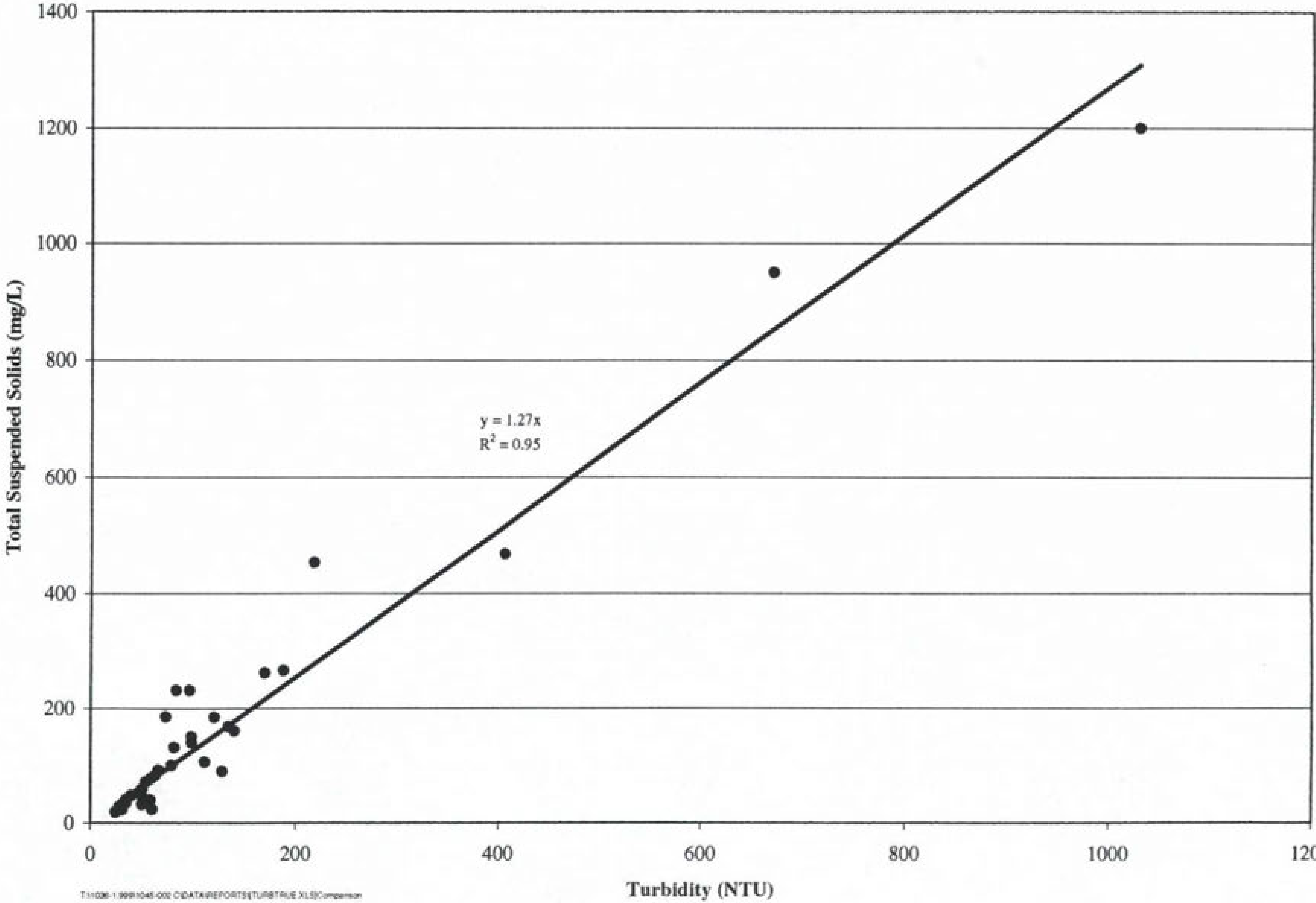


Figure 6-4

6.5 Assessment and Selection of BMPs for Runoff Quality Control

Classification of BMPs

BMPs are physical, structural and managerial practices that prevent or reduce *water pollution* and *changes in hydrology*. BMPs can be grouped into source controls, treatment controls, and streambank erosion controls. Given this overview, the purpose of this section is to provide a transition between the assessment of runoff quality and an assessment of the application of BMPs to suit conditions in Stoney Creek.

A Perspective on Recent Enabling Legislation

There is a desire by senior governments to have local governments take a more active role in stormwater management and environmental protection. To this end, the *Fish Protection Act (Bill 25)* and the *Local Government Statutes Act, 1997 (Bill 26)* were both given royal assent in late July 1997. The two acts significantly enable local government to extend their regulation of environmental stewardship.

Bill 26: New Tools for Environmental Protection

While the Fish Protection Act is a cornerstone of the recently announced *B.C. Fisheries Strategy*, Bill 26 is actually the key piece of legislation from a local government perspective because it:

- Complements the *Fish Protection Act*
- Amends the *Municipal Act*
- Provides local government with enabling tools to protect the natural environment, its ecosystems and biological diversity.

A key provision of Bill 26 is Section 907 dealing with runoff control. It states that "a local government may, by bylaw, establish the maximum percentage of the area of land that can be covered by impermeable material". Given the correlation between impervious area and the consequences for the environmental health of stream corridor, Section 907 has significant implications.

Regulation of Impervious Area

Local governments can now make requirements and set standards, including ongoing drainage management, to avoid adverse hydrological and water quality impacts. Section 907 is modelled after the provision that is in the *Vancouver Charter*.

Bylaws may be different for different zones, uses, sizes of paved areas, and terrain and water conditions. Thus, the objective in applying Bill 26 to developments within the Stoney Creek Watershed would be to require on-site measures that maintain the TIA at 29% (to 'hold the line') or reduce it (to 'improve conditions').

A Perspective on Bringing About Change

Development of the *Environmental Component* of an integrated stormwater management strategy requires an understanding of the need for integration of these three components:

- **Technical**: This refers to the results of a *cost-effectiveness analysis* to justify adopting the proposed regulatory tools

- **Political**: This refers to the challenges that are inevitably faced in being able to adopt the proposed regulatory tools

- **Legal**: This refers to the authority and the mechanics or procedural steps involved in adopting regulatory tools

The three components are closely linked. If the technical findings demonstrate the cost-effectiveness of a particular measure, then this should result in the *political acceptability* necessary to provide the *political will* to bring about change by adopting bylaws and regulations. Thus, for example, developing political support for source control management would be contingent on the effectiveness of an education program.

Framework for Environmental Planning Process

Bill 26 responds to local government requests for new and enhanced planning and regulatory tools. Key findings are highlighted as follows:

- **Can Local Government Do It?** The new legislation provides municipalities with the capability to develop a *toolbox* of regulatory options for source control management of municipal stormwater.

- **How Would Local Government Do It?** Having a toolbox to select from would enable a municipality to customize the *Environmental Component* of a stormwater management strategy to suit local concerns, needs, means and priorities.

- **Will Local Government Do It?** It is one thing for a senior government to enact enabling legislation. It is another matter for local elected officials to willingly accept responsibility to implement regulatory tools.

The Province and municipalities are venturing into uncharted territory. There are still many unanswered questions regarding the direction in which the "enabling process" is heading. Some of the new powers enabled in Bill 25 and Bill 26 do not have precedents in bylaw form. Several of these broad powers will require significant study and practice to create accurate definitions, realistic performance standards, and workable techniques.

Correlation of Impervious Area with Stream Corridor Health

The focus of the *Terms of Reference* is on water quality for aquatic life. Hence, it is essential to have a full and proper understanding of the factors affecting urban stream productivity and the *environmental health* of a creek corridor. Based on recent Washington State research, key findings are highlighted as follows:

- **Hydrology Threshold:** When the total watershed imperviousness is about 30% to 35%, the changes in hydrology are usually so significant that the watershed may be unable to sustain *abundant self-supporting* populations of cold water fish.

- **Water Quality Threshold:** When the total watershed imperviousness reaches 60%, the pollutant loading would theoretically be a significant factor in terms of fish survivability, except that the fish would already be gone (because the hydrological changes would have long since seriously degraded the habitat).

The TIA for the Stoney Creek watershed is presently about 29%, reflecting the beneficial impact of the forested Burnaby Mountain Park. It helps explain why fish are still present in Stoney Creek, and why water quality is still generally acceptable.

Customizing a BMP Strategy for Runoff Quality Control

Based on judgement and experience, customizing a 'BMP strategy' for runoff quality control in Stoney Creek should be shaped by these considerations:

- **Understanding Reality:** In the most urbanized portions of the watershed, the *changes in hydrology* have already occurred and little can be done to reverse them.

- **Making an Impact:** Improvements in runoff quality should be achievable through education, management programs, regulations and source controls.

- **Avoiding Capital Expenditures:** Until the sources of environmental impacts are addressed, there is little value in investing in watershed-wide 'structural BMPs' which are necessarily very expensive.

- **Solving Site-Specific and Chronic Problems:** Major capital investments should be made only to address specifically identified runoff quality impairments that remain after implementation of source control BMPs.

- **Risk Management:** Since accidents happen, provide a first line of defence by incorporating spill containment measures and installing oil/grit separators at strategic locations, thereby increasing emergency response capabilities.

A risk management program would be focussed on commercial and high-density neighbourhoods, and major traffic corridors (e.g. upgrade catch basins to provide spill containment at intersections with high accident rates).

6.6 Summary of Findings

Results of Baseflow Monitoring

The most significant finding is that nutrient concentrations (Nitrate-N) were somewhat high for this type of urban watershed. All the other tests showed good water quality conditions. The implications of the first finding are two-fold:

- May stimulate blooms of filamentous benthic algae.
- May cause potential increase in egg-to-fry mortality if NO_2^- present.

While the high nutrient levels may be a seasonal phenomenon related to lawn maintenance, they underscore the possible need for a source control program.

Results of Storm Event Monitoring

The most significant findings are listed below:

- Nitrate-nitrogen remained high in spite of dilution effects.
- Copper concentrations exceeded federal-provincial water quality guidelines.
- Total suspended solids (TSS) were greater than 100 mg/L for less than 7 hours.
- A relationship has been derived between turbidity and TSS.

While the nutrient levels may stimulate blooms of filamentous benthic algae, the effects of the copper and TSS levels on fish would be sub-lethal.

Phased Approach to Implementation of a BMP Strategy for Runoff Quality Control

A proposed 4-step strategy for phasing in a BMP strategy is summarized as follows:

- **Step #1:** Provide spill containment at high risk locations.

- **Step #2:** Invest in public education, maintenance management programs, and source control regulations first.

- **Step #3:** Monitor the foregoing activities to assess their effectiveness in addressing runoff quality concerns, problems and issues.

- **Step #4:** If source control BMPs are not sufficient, then selectively invest in capital improvements to address specific problems.

Looking ahead to Chapter 7, future detention facilities should be *wet ponds* that serve a dual function in mitigating the *frequently occurring storms:* prevent watercourse destabilization due to changes in hydrology (i.e. the hydrotechnical function); and preserve aquatic habitat and remove pollutants (i.e. environmental function).

CHAPTER 7

CONCEPT PLANNING FOR INTEGRATED STORMWATER MANAGEMENT

7.0 CONCEPT PLANNING FOR INTEGRATED STORMWATER MANAGEMENT

7.1 Introduction

The Challenge

Chapters 1 through 6 are the building blocks that provide the foundation for an integrated stormwater management strategy. Chapter 7 provides the framework for strategy implementation. It synthesizes concepts, information and decisions as they have evolved through the participatory process involving the Steering Committee.

Committee members have acknowledged that the process of developing an integrated strategy is complex. Therefore, an underlying objective of this chapter is to present the outcome of that process in as straightforward a manner as possible so that it will be clear as to how decisions have been made.

One of the implicit challenges is to elaborate on the policy implications of seemingly straightforward concepts for achieving the goal of 'holding the line' and over time progressively 'improving conditions' in the Stoney Creek system.

Framework for Strategy Implementation

This chapter comprises four sections that provide a framework describing *how* to achieve the vision described in the paragraph above. The scope of each section is highlighted below:

- **Elements of a Concept Plan for Ecosystem Protection:** Identify achievable elements of a comprehensive and holistic strategy for mitigating *changes in hydrology* and preventing *water pollution*.
- **Elements of a Concept Plan for Property Protection:** Incorporate the results of a risk management assessment that considers both the hydraulic and physical adequacy of culvert installations, and establish priorities for a long-term program of rehabilitation and/or replacement.
- **Capital Cost Implications for Drainage System Improvements:** Generate order-of-magnitude cost estimates to provide a basis for initial decision-making related to an implementation plan that could be presented to elected officials.
- **Integration with Brunette Watershed Management Plan:** Provide direction as to how the 'Stoney Creek model' could be applied to other Brunette tributaries.

The final decision on *whether* to proceed will be made by the Council of each participating municipality. That decision will be heavily influenced by the cost implications, and the 'willingness to pay' by the public to reduce environmental risks.

7.2 Elements of a Concept Plan for Ecosystem Protection

Outcome of Workshop Process

The two-part Figure 7-1 represents the *Environmental Component* of an integrated master drainage plan. It is the outcome of the 6-step process in evolving a shared vision (at the Committee level) of an achievable strategy for 'improving conditions' over time in Stoney Creek, and is consistent with the vision for the Brunette Basin.

For reference and documentation purposes, the two graphics that provided the basis for discussion and decision-making at the August and September workshops are included in Appendix C. Viewed in conjunction with the two-part Figure 7-1, the four graphics show the evolution of the plan elements.

Distinction between Environmental and Hydrotechnical Components

Chapter 2 introduced the following table to illustrate the two components of an 'integrated strategy' that considers the full range of runoff events:

Component	Management Objective	Hydrotechnical Focus	Type of Impact
Hydrotechnical	Protect Property	Infrequently Occurring Large Storms	Dramatic (flood and erosion damage resulting from peak flows)
Environmental (Enhanced Hydrotechnical)	Protect Ecosystems	Frequently Occurring Small Storms	Insidious (water quality deterioration, watercourse erosion and sedimentation resulting from the increased number of runoff events per year.)

The hydrotechnical component is addressed in Section 7.3, and is driven by flood and erosion risk management.

Identification of Sub-Watershed Management Units

For the purposes of this study, the Stoney Creek watershed comprises two 'management units' as described below:

- **Western Sector:** This encompasses Simon Fraser University (SFU) and the existing urban area at the base of Burnaby Mountain.
- **Eastern Sector:** This encompasses the upland Coquitlam and Port Moody tributary area, and the Lougheed Town Centre Area in the valley.

The main channel stem is the boundary between the two sectors (i.e. as far as the Burnaby/Coquitlam border). The main channel, in turn, comprises six reaches within Burnaby and two within Coquitlam. The three tributaries are in the Western Sector.

Factors Limiting the Ecological Values of Urban Streams

The previously introduced Figure 2-4 is a key graphic because it provides a roadmap for a comprehensive approach to ecosystem protection and enhancement. As explained in Chapters 2 and 3, it ranks the four major factors limiting the environmental values of urban streams as follows:

- Changes to hydrology
- Loss of riparian corridors
- Loss of physical habitat
- Water quality degradation

In Chapter 3, these four factors provided the basis for the set of three decision-making tables (that described three scenarios) corresponding to varying levels of environmental protection, specific objectives to achieve the levels, measurable criteria to test achievement, and actions needed to achieve the desired results.

Framework for Watershed Management

Table 7-1 builds on that foundation, and in turn, presents a comprehensive framework for action to initially 'hold the line' and then over time 'improve conditions' in the Stoney Creek watershed to achieve the Brunette Vision. It is a key deliverable.

Table 7-1 synthesizes key findings from previous chapters, notably Chapters 5 and 6. The objective is to provide a clear picture of what needs to be done to address each of the four factors. The findings are organized in terms of three categories: Western Sector, Eastern Sector and Main Stem.

Time-Line Concept for Making Stream Stewardship a Reality

The previously introduced graphic conceptualizing *MDP Levels* (i.e. Figure 2-5) is a decision-making tool that also illustrates the 'time-line concept' for implementing an holistic strategy for watershed management:

MINIMUM TIME HORIZON	IDENTIFICATION OF MINIMUM GOALS
Within 20 years	The goal would be to reach *Level 3* (i.e. as an average condition)
After 20 to 50 years	Building on success in the first 20 years, strive for *Level* 4 in the decades following

Having a time-line provides a reality check. It also underscores the importance of achieving initial successes in order to build support for the long-term strategy.

TABLE 7-1

COMPREHENSIVE STRATEGY FOR STORMWATER MANAGEMENT AND ECOSYSTEM PROTECTION IN THE STONEY CREEK WATERSHED

GOALS AND RANKING❶❷	WESTERN SECTOR DRAINAGE AREA		MAIN STEM (UP TO NORTH ROAD)		EASTERN SECTOR DRAINAGE AREA	
	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)	Level 3 - Hold the Line (20-Yr. Vision)	Level 4 - Improve Conditions (50-Yr. Vision)
	Maintain EIA at '98 Level of 29%❷	Reduce EIA Below 20%	Maintain EIA at '98 Level of 23%	Reduce EIA Below 20%	Maintain EIA at '98 Level of 31%	Reduce EIA Below 20%
Hydrology	For new development and/or redevelopment, mitigate changes in hydrology by providing a combination of: ➢ on-site stormwater detention ➢ impervious area reduction ➢ off-site diversion and detention	For existing development and/or re-development, mitigate the frequently occurring storms by a combination of: ➢ on-site detention ➢ impervious area reduction ➢ a regional detention facility at a site in the vicinity of the Cariboo Dam	➢ For new development and/or redevelopment in watershed, provide a combination of on-site detention and impervious area reduction ➢ replace culverts with "bridged" crossings	For existing development in watershed, intercept runoff from the frequently occurring events and divert to the regional ponds	For re-development, mitigate changes in hydrology (due to land use densification) by providing a combination of: ➢ on-site detention ➢ impervious area reduction	For existing development and/or re-development, mitigate the frequently occurring storms by a combination of: ➢ impervious area reduction ➢ on-site detention ➢ regional detention facilities at two locations
Riparian Corridor	For the three tributaries: ➢ re-plant disturbed portions of corridors to restore native vegetation ➢ Ensure "no net loss" of riparian buffer width or vegetation	For the three tributaries: ➢ consider acquiring additional right-of-way width (in conjunction with future land re-development) if required to achieve possible greenway objectives ➢ increase the "effective width" of undisturbed vegetation to a minimum 30 m (each side) for at least 60% of corridor length	➢ re-plant disturbed portions of the corridor to restore native vegetation ➢ re-develop a trail system that achieves a balance between human access and fish protection ➢ mitigate the impact of the existing GVRD access road	➢ consider acquiring additional right-of-way width (in conjunction with future land re-development) to achieve possible greenway objectives ➢ increase the "effective width" of undisturbed vegetation to minimum 50 m (each side) for at least 60% of corridor length	For Main Stem above North Road (i.e. in Coquitlam and Port Moody) ➢ develop a partnership with the local community to foster awareness of ecosystem values ➢ ensure "no net loss" of riparian buffer width or vegetation	For Main Stem above North Road (i.e. in Coquitlam and Port Moody) ➢ consider acquiring ownership of a *Riparian Habitat Buffer Zone* (for 30m minimum each side of channel) in conjunction with future land redevelopment ➢ re-establish native vegetation within the buffer strip for at least 60% of the corridor length
Aquatic Habitat	For the three tributaries: ➢ through the volunteer Streamkeepers Program, continue to implement in-stream improvements as identified by the SCEC and as validated through the Steering Committee process ➢ rehabilitate culverts to minimize barriers to fish passage❺	For the three tributaries: ➢ place the highest priority on protecting and enhancing Tributary #3 ➢ identify opportunities to recreate physical habitat through an aggressive program of channel improvements along full length ➢ replace culverts with "bridged" crossings to eliminate barriers and enable fish passage to upstream habitat	➢ for new development and/or redevelopment in watershed, provide a combination of on-site detention and impervious area reduction ➢ through the volunteer Streamkeepers Program, continue to implement in-stream improvements ➢ replace culverts with "bridged crossings	➢ intercept runoff from the frequently occurring events and divert to the regional ponds ➢ recreate physical habitat through side-channel construction and/or main channel improvements ➢ achieve a pool/riffle ratio of approximately 50/50 ➢ utilize benthic monitoring to locate and mitigate sources of degradation	For Main Stem above North Road ➢ through the voluntary Streamkeepers Program, and in partnership with local landowners, identify potential opportunities for habitat enhancement and where possible implement minor channel improvements for resident fish	For Main Stem above North Road ➢ through a partnership initiative with local landowners, consider recreating resident fish habitat within the *Riparian Habitat Buffer Zone* ➢ investigate the feasibility of "daylighting" the channel in the upper reaches (i.e. through the school property)
Water Quality	For Burnaby only: ➢ invest in public education, maintenance management programs, and source control regulations ➢ review and update spill response procedures ➢ provide for spill containment (deleterious substances) at high risk locations	For Burnaby only: ➢ utilize the proposed regional detention facility for pollutant removal and/or treatment ➢ strive to comply with future Federal/Provincial/municipal guidelines for all quality parameters	➢ continue with sanitary sewer rehabilitation program to reduce exfiltration (and hence, coliform counts) ➢ stabilize erosion sites to minimize sediment loading	➢ intercept "first flush" runoff and divert to regional ponds ➢ strive to comply with future Federal/Provincial/municipal guidelines for all quality parameters	For all three municipalities: ➢ invest in public education, maintenance management programs, and source control regulations ➢ review and update spill response procedures ➢ provide for spill containment (deleterious substances) at high risk locations.	For all three municipalities: ➢ utilize the proposed regional detention facility at the Tributary #3 confluence for pollutant removal and/or treatment For Burnaby only: ➢ utilize the proposed regional detention facility near the Lougheed Highway for pollutant removal and/or treatment

Cost for Flood Risk Management (to protect property)	$0.6 M for storm sewer upsizing in Burnaby to prevent flood overflows that would otherwise cause property damage	-	➢ $5.0 M for culvert replacements in Burnaby❹ ➢ $0.5 M for culvert replacement at North Road❹			-
Cost for Environmental Risk Management (to protect ecosystems)	-	➢ $6.5 M for flow interception and detention/treatment in Burnaby❸ to partially restore natural hydrology and prevent water pollution	-	-	-	➢ $4.0 M for flow interception and detention/treatment to serve all three municipalities❸ ➢ $4.0 M for flow interception and detention/treatment to serve Burnaby❸

❶ Ranking based on results of research by the *Center for Urban Water Resources Management* at the University of Washington (Seattle), regarding the impacts of land use changes on the environmental health of urban streams.
❷ EIA = Effective Impervious Area. By definition, this is impervious surfaces with direct hydraulic connection to drainage or stream system. These are estimated values based on applying an 80% factor to TIA. For the overall watershed, computer model calibration resulted in a close correlation with the 23% level. For the Western Sector, and as decided in consultation with the Steering Committee, the EIA calculation excludes Burnaby Mountain Park. (Note: Including the park, the EIA is 17%).
❸ The investment in flow interception in the Eastern and Western Sectors would have a spin-off benefit for flood risk management in the Main Stem. The benefit would be in terms of the reduced potential for debris transport and blockage.
❹ The investment in culvert replacement would have a spin-off benefit for environmental risk management in the Main Stem by creating opportunities for habitat enhancement, and by reducing the potential for flood damage.
❺ All existing culverts on Tributary #1 and #2 are rated as inadequate from an environmental perspective, but are considered acceptable installations in terms of overall conformance with the *Guidelines for Effective Culvert Design*.

Achievable Goals For Environmental Protection

Table 7-1 establishes specific goals for each management unit within the context of:

- the over-arching framework provided by the *Brunette Vision;*
- the overall goals for the study area; and
- the time-line concept for achieving those goals.

Furthermore, Table 7-1 correlates the goals with EIA to provide a target level for mitigating *changes in hydrology* and preventing *water pollution*. Since the EIA indicator is the key element shaping the strategy and direction for the Stoney Creek watershed, it is important to reiterate the following understanding:

- **Consequences of Changes in Hydrology:** Replacement of native ground cover with impervious surfaces results in an increased frequency of occurrence of threshold levels of runoff from 'small storms', and this in turn triggers watercourse erosion and sedimentation processes that then degrade or eliminate aquatic/riparian habitat.

- **Total Impervious Area (TIA):** The fraction of the Stoney Creek watershed covered by constructed, non-infiltrating surfaces (such as concrete, asphalt and buildings) is 29%.

- **Effective Impervious Area (EIA):** EIA is defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system, and therefore excludes some paved surfaces that may contribute nothing to the storm-runoff response of the downstream system. (For Stoney Creek, it is estimated that the EIA is approximately 80% of the TIA, and is therefore about 23%).

Most urban watersheds in the Pacific Northwest eco-region may be unable to sustain *abundant self-supporting* populations of cold water fish once the EIA exceeds 30%. The Stoney Creek ecosystem still supports spawning and rearing populations of coho and steelhead trout, as well as resident and sea-run cutthroat trout; with the presence of steelhead and anadromous cutthroat trout being particularly significant because of their rare occurrence in urban streams.

Achieving the overall goal of 'holding the line' (*Level 3 MDP)* means implementing measures that prevent the EIA from exceeding the 1998 level of 23%. Achieving the overall goal of 'improving conditions' (*Level 4 MDP*) means reducing the EIA below the 20% threshold.

Measures to achieve these goals would comprise a combination of on-site stormwater detention, on-site impervious area reduction, flow diversion around high value creek reaches, and regional detention. Diversion and detention would represent a fallback position if on-site measures were not effective in achieving the target EIA level.

Stormwater Management Strategy for Simon Fraser University

In the Western Sector, new development will be concentrated within the Ring Road at SFU. The two options for achieving the goal of maintaining pre-development stormwater runoff rates, volumes and seasonal variations are summarized below:

- **On-Site Mitigation (Preferred):** Construct detention vaults and/or incorporate innovative measures in building design to achieve impervious area reduction objectives. This study has established a philosophy and design criteria for stormwater management, and has generated preliminary storage volumes for feasibility assessment purposes. The next step is for SFU to determine whether (or what proportion) of the required storage can in fact be provided on-site.
- **Off-Site Mitigation (Fallback):** Contribute to funding of a regional system serving the entire Western Sector. A decision on this cannot be made until after SFU completes the feasibility assessment for the *On-Site Option*.

Based on a number of simplifying assumptions with respect to the types of residential development anticipated at SFU, an order-of-magnitude estimate of the storage volume necessary to 'hold the line' (Level 3) is 20,000 m^3 for the roughly 40 hectares of proposed residential development within the Ring Road. Of significance, only about one-third of this new development falls within the Stoney Creek watershed. This provides a starting point for determining what combination of storage and impervious area reduction measures will be necessary to mitigate *changes in hydrology* related to the small storms.

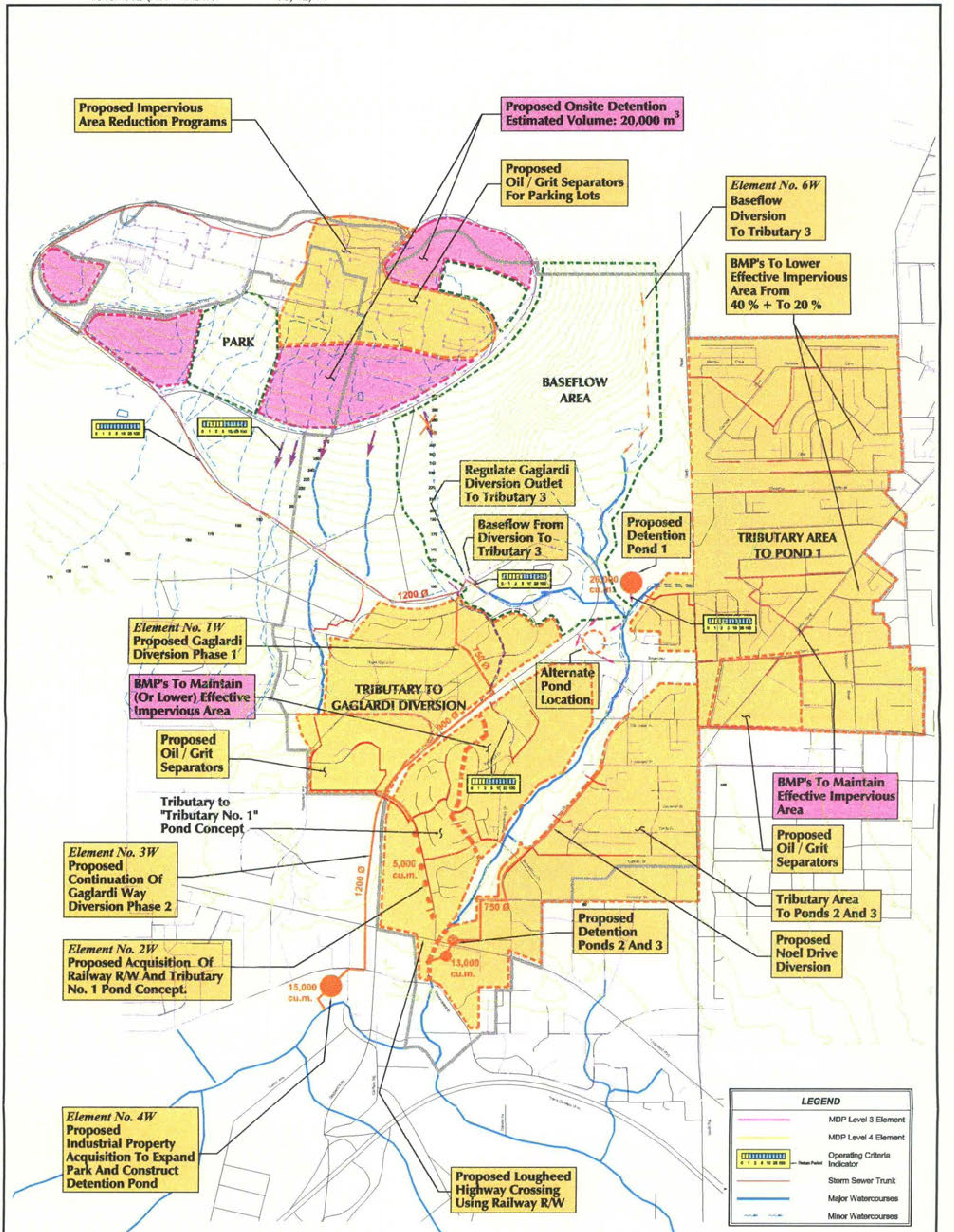
Planning Framework for Environmental Risk Management

One of the outcomes of the workshop process was the decision to present two variations of the *Plan for Environmental Risk Management* to reflect a range of possible future directions for project implementation:

- **Figure 7-1A (On-Site Mitigation Achievable at SFU):** If 'changes in hydrology' can be mitigated on-site to 'hold the line' (Level 3), then the off-site elements would be colour-coded orange. This means they would only be implemented if a community decision was made to 'improve conditions' (Level 4) over time.
- **Figure 7-1B (Off-Site Mitigation Necessary for SFU):** If mitigation cannot be achieved on-site, then the off-site elements would be colour-coded pink because they would be required immediately to 'hold the line' (Level 3).

The two plans are identical, with two exceptions: Figure 7-1A shows smaller downstream pipe sizes if SFU achieves on-site mitigation; and Figure 7-1B shows the trunk sewer system being extended along University Drive. The issue of what is an appropriate cost-sharing formula between SFU and Burnaby is beyond the scope of this report. It must be emphasized that *On-Site Mitigation* is preferred by the Committee. *Off-Site Mitigation* would only be considered if the on-site option cannot be fully realized.

1045-002\FIG7-1A.DWG 98/12/14



250 0 250
Scale In Metres

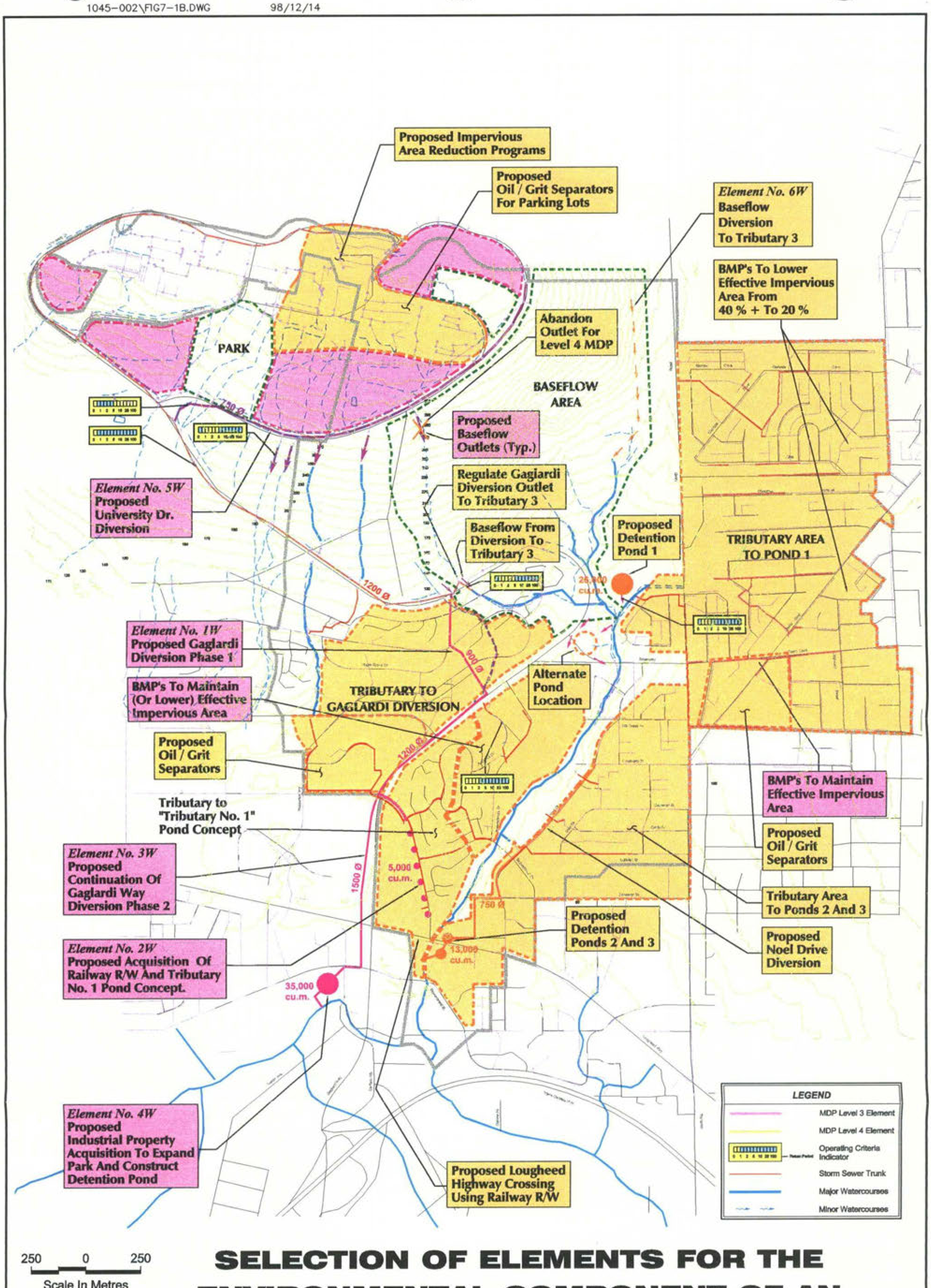
SELECTION OF ELEMENTS FOR THE ENVIRONMENTAL COMPONENT OF AN INTEGRATED MASTER DRAINAGE PLAN

OPTION 1 - SFU ONSITE STORAGE

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

FIGURE 7-1A

1045-002\FIG7-1B.DWG 98/12/14



SELECTION OF ELEMENTS FOR THE ENVIRONMENTAL COMPONENT OF AN INTEGRATED MASTER DRAINAGE PLAN

OPTION 2 - SFU OFFSITE STORAGE AND DIVERSION

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

FIGURE 7-1B

Concept for a Regional Stormwater System Serving the Western Sector

A regional system serving the Western Sector could comprise a combination of these elements for mitigation of the *frequently occurring storms* to 'improve conditions' in Tributary #3 and the Main Stem:

- **Gaglardi Way Phase 1 Diversion (Element #1W):** Re-direct runoff from SFU (i.e. that portion over and above 50% of the pre-development Q_2 rate) via a piped diversion to either Tributary #1 or the Brunette River. Bypass storms greater than Q_5 back to Tributary #3.
- **Gaglardi Way Phase 2 Diversion (Element #2W):** Continue the piped diversion south to the Brunette.
- **Western Sector Detention Facility (Element #3W):** Expand the park near Cariboo Dam to incorporate a large-scale detention pond with sufficient operating volume to provide for the entire urbanized area in the Western Sector. (Note: Provide 15,000 m^3 plus an additional 20,000 m^3 for SFU if on-site mitigation not achievable.)
- **Burlington Northern Right-of-Way Detention (Element #4W):** Construct a series of cascading ponds (totalling 5,000 m^3) and possibly incorporate habitat improvements to replace Tributary #1.
- **University Drive Interceptor (Element #5W):** If on-site mitigation is not fully achievable at SFU, then install a branch interceptor up the south half of the Ring Road to connect the new development area to the existing Gagliardi Way system.
- **Tributary #3 Baseflow Enhancement (Element #6W):** Construct an open channel diversion along the mountainside.

The accompanying Table 7-2 summarizes the pros and cons for each element as evaluated through the workshop process. Again, it must be emphasized that *Off-Site Mitigation* for SFU represents a 'fallback position' if the on-site option cannot be fully realized. Also, a regional system is contingent on a community decision to 'go all the way' to achieve Level 4.

Implications for Brunette River System

At the August 1998 Workshop, the concept for bypassing flows around Reaches 1 and 2 was presented to protect the highest value section of the Stoney Creek system. The Committee concluded that it would not be acceptable to simply discharge directly into the Brunette River. Hence, the reason for the Western Sector Detention Facility.

Given the need to also protect the aquatic resources in the Brunette, the Committee decided that any flow diversion plan for Stoney Creek must include provision for a detention facility at the confluence with the Brunette. Of relevance, however, a detailed hydraulic analysis may demonstrate that the Brunette flow regime would not be significantly changed.

DECISION TREE FOR A REGIONAL STORMWATER SYSTEM SERVING THE WESTERN SECTOR OF THE STONEY CREEK WASTERSHED

If there is a political will to move forward incrementally with an *Ecosystem Approach* that integrates stormwater and stream corridor management (Decision #1), then the *Watershed Environmental Goal* is:

Mitigate the frequently occurring storms to hold the line (Level 3) at the time of land development, and over time improve (Level 4) the Stoney Creek stream corridor ecosystem.

▼

1ST STEP - GO PART WAY TO AT LEAST ACHIEVE LEVEL 3
(TO MITIGATE NEW DEVELOPMENT AT SFU)

Protect Tributary #3 and the Main Stem of Stoney Creek (above Lougheed Highway) through implementation of source controls at SFU to maintain before-development hydrology. **(Decision #2)**

OR ALTERNATIVELY

If on-site measures cannot be fully realized to protect Tributary #3 and Main Stem above Lougheed Highway, then construct the downstream $1 million Gaglardi Way Phase 1 Diversion (to bypass Tributary #3) **PLUS** the upstream University Drive Interceptor Extension. **(Decision #3)**

AND

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing either the $2.5million Gaglardi Way Phase 2 Diversion and the first phase of the $3 million Western Sector Detention Facility **OR** the $1.0 million Burlington Northern Right-of-Way Detention. **(Decision #4)**

▼

2ND STEP - GO ALL THE WAY TO ACHIEVE LEVEL 4
(TO MITIGATE THE ENTIRE WESTERN SECTOR DEVELOPED AREA)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by systematically and progressively achieving EIA reduction targets through a comprehensive and long-term program of source-control measures in all three municipalities. **(Decision #5)**

OR ALTERNATIVELY

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $2.5 million Gaglardi Way Phase 2 Diversion (to bypass the Main Stem) **PLUS** the $3 million Western Sector Detention Facility to serve all development **(Decision #6)**

FIGURE 7-2

TABLE 7-2

DECISION ANALYSIS FOR A REGIONAL STORMWATER SYSTEM SERVING THE WESTERN SECTOR OF THE STONEY CREEK WATERSHED

Stormwater Management Element		Advantages	Disadvantages
No.	Description	(Pros)	(Cons)
1W	*Gaglardi Way* *Phase 1 Diversion* ♦ Remove storm events up to a 5-year return period (Q_5) and convey to either Tributary #1 or Brunette River ♦ Bypass storm events greater than Q_5 back to Tributary #3 ♦ Bypass flows less than 0.5 Q_2 back to Tributary #3 ♦ Design diversion flow = 4.5 cms ♦ Preliminary size selection = 1200 mm ∅ ♦ Install in road R/W	♦ Protects/enhances Tributary #3 by partially restoring the natural hydrology❺ ♦ Protects/enhances Reaches 3 to 5 in the Main Stem by partially restoring the natural hydrology ♦ Mitigates chronic and/or significant bank erosion and instability in the Main Stem by removing flows that cause 'wear-and-tear' ♦ Provides flexibility to accommodate new development at SFU if on-site detention and impervious area reduction measures cannot accomplish self-mitigation ♦ Have better access for regular maintenance because flow would be piped within a right-of-way ♦ May result in a possible bioengineering opportunity for Tributary #1❹ ♦ May result in possible multiple use options for the Tributary #1 right-of-way❹ ♦ First stage leading to a regional detention pond❸	♦ Results in potential utility conflict with BC Gas ♦ Need for capital expenditure to construct the piped diversion ♦ Results in ongoing maintenance costs ♦ Results in short-term environmental impacts during construction ♦ Contingent on City acquiring the right-of-way from Burlington Northern❹ ♦ Results in higher stream flows in Tributary #1❹
2	*Gaglardi Way* *Phase 2 Diversion* ♦ Design diversion flow = 5.5 cms ♦ Preliminary size selection = 1500 mm ϕ ♦ Install in R/W ♦ Convey flow from Lake City intersection south to the regional detention facility	♦ Protects/enhances Tributary #3 by partially restoring the natural hydrology ♦ Preserves/enhances Reaches 1 and 5 in the main stream by partially restoring the natural hydrology ♦ Does not require acquisition of Burlington Northern right-of-way ♦ Second stage leading to a regional detention pond that would enable *Level 4* to be achieved❸ ♦ Provides flexibility to accommodate SFU should on-site mitigation not be fully achievable❺	♦ Need for capital expenditure to construct the piped diversion ♦ Results in ongoing maintenance costs
3W	*Western Sector* *Detention Facility* ♦ Develop a site near Cariboo Dam and incorporate in existing park ♦ Serves the existing developed area on the east side of Gaglardi Way, and potentially SFU ♦ Required operating storage = 15000 ± m³ to achieve *Level 4* within existing urban area = 20,000 ± m³ extra to accommodate new development at SFU ♦ Size for Q_2 post-development and release at 0.5 Q_2 for existing development condition ♦ SFU volume based on Q_5 inflow	♦ Enables *Level 4* to be achieved by mitigating 'changes in hydrology' for existing development ♦ Provides flexibility for expansion to accommodate SFU should on-site mitigation not be fully achievable ♦ Preserves/enhances Reaches 1 and 2 in the Main Stream❶ ♦ Protects Tributary #1 and Tributary #3 ♦ Does not require storage in Tributary #1 ♦ Provides opportunity for water quality improvement ♦ Provides opportunity for habitat creation ♦ Provides some protection for aquatic resources in the Brunette system	♦ Need for land acquisition ♦ Need for capital expenditure to construct the pond ♦ Need for contaminated site remediation ♦ Need to resolve hydraulic issues to make the concept work ♦ Results in ongoing maintenance cost ♦ Does not provide any benefit beyond Q_5 ♦ May not have a measurable impact on the Brunette flow regime ♦ Does not serve the area on the east side of Gaglardi Way; that area will require on-site measures to mitigate "changes in hydrology'
4W	*Burlington Northern* *Right-of-Way Detention* ♦ Construct a series of cascading linear ponds ♦ Maximum developable operating storage (total) = 5000 m³ (based on flooding R/W to a 1m depth above existing railway bed) ♦ Release rate to be 0.5 Q_2 for existing development condition	♦ Protects/enhances tributary #3 by partially restoring the natural hydrology❶ ♦ Protects/enhances Reaches 3 to 5 in the Main Stem by partially restoring the natural hydrology❶ ♦ May result in possible bioengineering opportunity for tributary #1 ♦ May result in possible multiple use options for the Tributary #1 right-of-way ♦ May address existing habitat and water quality concerns	♦ Contingent on City acquiring the right-of-way from Burlington Northern ♦ Results in higher peak flows in Tributary #1 ♦ Need for capital expenditure to construct cascading ponds ♦ Developable storage insufficient to fully mitigate existing urban area (i.e. 15000 m³ needed vs 5000 m³ potentially available) ♦ Would require on-site measures to fully mitigate for redevelopment ♦ Constrained opportunity for habitat improvements ♦ Results in short-term environmental impacts during construction ♦ Results in ongoing maintenance costs
5W	*University Drive Interceptor* ♦ Off-site cost directly attributable to new development at SFU ♦ Convey flow to existing Gaglardi Way trunk sewer (i.e. if on-site mitigation not fully achievable) ♦ Size for Q_5 post-development; and bypass storm events greater than Q_5 and less than $0.5Q_2$ to creek systems ♦ Design Diversion Flow = 1.4 cms ♦ Preliminary Size Selection = 750 mm ø	♦ Protects/enhances Tributary #3 and Main Stem by partially restoring the natural hydrology	♦ Results in short-term environmental impacts during construction
6W	*Tributary #3* *Baseflow Enhancement* ♦ Investigate feasibility of constructing an interceptor channel across the mountainside ♦ Connect to the north branch of Tributary #3	♦ Should enhance the fisheries values in Tributary #3 ♦ Should enhance the fisheries values in the Main Stem in most years ♦ Results in a bioengineering opportunity for the diversion channel	♦ Need for capital expenditure to construct the open channel diversion ♦ Results in short-term environmental impacts during construction ♦ Results in ongoing maintenance costs for the diversion channel ♦ Removes base flow from the upper reaches of the Main Stem ♦ No baseflow in a dry summer (e.g. 1998)

Explanatory Note: ❺Indicates that the element is cross-referenced to a second element (e.g. ❺ refers to Element No. 5W).

p\w\112V25464

Selection of Elements for Improving the Stream Corridor Ecosystem

Figure 7-2 complements Table 7-2 by presenting a simplified decision tree that conceptualizes the series of decisions that would need to be made to achieve the long-term goal of improving conditions in the Stoney Creek stream corridor (i.e. as defined by a *Level 4 MDP*). Key observations are highlighted as follows:

- Before anything can happen, there needs to be a political will to make something happen (Decision #1).

- Once that first decision is made, Decisions #2 through #5 depend on the results of feasibility assessments that are beyond the scope of the present study.

- A regional system would provide flexibility to accommodate residential development at SFU (Decision #3) if it is not feasible to fully achieve runoff-reduction objectives within the Ring Road.

- From a watershed perspective, selection of the *Gaglardi Way Phase 2 Diversion* provides better long-term flexibility than does the *Burlington Northern R/W Detention* (Decision #4). However, there would still be an option to enhance the corridor as a greenway for people and fish.

- Although a number of unknowns need to be resolved before either Decision #5 or Decision #6 can be made, a large-scale detention facility would result in multi-objective opportunities for both the Brunette and Stoney.

Based on the evaluation of inputs as presented in Table 7-2, and subject to *On-Site Mitigation* not being fully realized at SFU, the preferred elements of the core *Environmental Component* of an integrated master plan would be both phases of the Gaglardi Way diversion, plus a regional detention facility. In Section 7.4, order-of-magnitude cost estimates are presented to enable elected officials to make Decision #1.

Finally, it is suggested that baseflow enhancement in Tributary #3 would be preferable to continuing to route that same flow through the urbanized upper Main Stem. In a dry summer, however, there may be no flow to divert.

Benefits of a Regional System Serving the Western Sector

For a Level 4 strategy, the benefits in mitigating the *frequently occurring storms* by implementing the 'core elements' as shown on Figure 7-1 would be two-fold:

- Improve conditions in the two highest value reaches of the Stoney Creek system.
- Protect the beneficial uses of the Brunette receiving water system.

As a 'fallback position', the proposed elements would also accommodate land development at SFU while sustaining natural systems.

DECISION TREE FOR A REGIONAL STORMWATER SYSTEM SERVING THE EASTERN SECTOR OF THE STONEY CREEK WASTERSHED

If there is a political will to move forward incrementally with an *Ecosystem Approach* that integrates stormwater and stream corridor management (Decision #1), then the *Watershed Environmental Goal* is:

Mitigate the frequently occurring storms to hold the line (Level 3) at the time of land redevelopment, and over time improve (Level 4) the Stoney Creek stream corridor ecosystem.

▼

1ST STEP - GO PART WAY TO AT LEAST ACHIEVE LEVEL 3
(TO MITIGATE RE-DEVELOPMENT)

Protect the Main Stem of Stoney Creek (all the way to the Brunette confluence) through implementation of source controls in conjunction with land redevelopment to maintain the before-redevelopment hydrology. **(Decision #2)**

▼

2ND STEP - GO ALL THE WAY TO ACHIEVE LEVEL 4
(TO MITIGATE THE ENTIRE EASTERN SECTOR DEVELOPED AREA)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by systematically and progressively achieving EIA reduction targets for the entire Eastern Sector through a comprehensive and long-term program of source-control measures supported by bylaws and regulations in all three partner municipalities. **(Decision #3)**

OR ALTERNATIVELY, AND
CONSIDERING ONLY THE COQUITLAM/PORT MOODY TRIBUTARY AREA

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $4 million Tri-Municipalities Detention Facility near the confluence of Tributary #3 and the Main Stem. **(Decision #4)**

OR ALTERNATIVELY, AND
CONSIDERING ONLY THE LOUGHEED TOWN CENTRE AREA
(north of Cameron Street)

Protect and/or enhance the Main Stem of Stoney Creek (all the way to the Brunette confluence) by constructing the $2 million Noel Drive Interceptor Sewer (to intercept existing outfalls) **PLUS** the $2 million Loughheed Town Centre Area Detention Facility (south of the Lougheed Highway). **(Decision #5)**

FIGURE 7-3

Concept for a Regional System Serving the Eastern Sector

Figure 7-3 is a decision tree for a regional system serving the Eastern Sector, and is complemented by Table 7-3. The Eastern Sector system would comprise two subsystems as described below:

- **Coquitlam/Port Moody Tributary Area:** Two possible locations have been identified for a large-scale detention pond that would primarily serve the Coquitlam/Port Moody drainage area. Both locations are in Burnaby. The preferred location is the one located on the north side of the confluence of Tributary #3 and the Main Stem. This site could be developed as an on-line pond, with an operating volume in the order of 26,000 m^3.
- **Lougheed Town Centre Area:** Two possible locations for large-scale ponds have been identified south of the Lougheed Highway. The minimum total required volume would be 13,000 m^3. Their primary purpose would be to serve the area north of the Lougheed Mall as shown on Figure 7-1. This would require construction of a trunk sewer to intercept existing outfalls and convey the drainage south.

Similar to the Western Sector, before anything can happen, there needs to be a political will to move in the direction of a *Level 4 MDP (Improve Conditions)*. If there is, then the next decision is to designate and secure the proposed sites for future construction of detention ponds.

Program for Impervious Area Reduction in the Eastern Sector

The fact that the Eastern Sector could possibly be completely redeveloped over the next 50 years would seem to provide an opportunity to implement bylaws and regulations that achieve residential runoff-reduction objectives on-site. As discussed in Chapter 6, Bill 26 enables local government to establish requirements and set standards.

As redevelopment takes place, the goal would be to progressively lower the EIA (Effective Impervious Area) from the present 31% to less than 20%, through the application of BMPs such as roof leader disconnection. This would be the goal of a *Level 4 MDP*.

Achieving this goal would involve reducing, by half, the impervious surface area that has a direct hydraulic connection to the downstream drainage system. Based on the Surrey experience in the Bear Creek watershed, this is possible. In Bear Creek, the EIA of less than 20% compares with a TIA (Total Impervious Area) of almost 40%.

If this long-term goal could be achieved, this would considerably lower both the TIA and EIA for the overall watershed. In the meantime, and as a minimum objective, redevelopment of existing residential or commercial areas must not result in the existing 23% EIA level for the overall watershed being exceeded.

TABLE 7-3

DECISION ANALYSIS FOR A REGIONAL STORMWATER SYSTEM SERVING THE EASTERN SECTOR OF THE STONEY CREEK WATERSHED

Stormwater Management Element		Advantages (Pros)	Disadvantages (Cons)
No.	**Description**		
1E	***Tri-Municipalities Detention Facilities*** ♦ Develop a site near the confluence of the Main Stem and Tributary #3 ♦ Required operating storage = 26000 ± m^3 ♦ Size for Q_2 post-redevelopment and release at 0.5 Q_2 for existing development condition	♦ Protects/enhances the Main Stem by partially restoring the natural hydrology ♦ Enables Level 4 to be achieved by mitigating 'changes in hydrology' for existing development ♦ Provides opportunity for water quality improvement ♦ Provides opportunity for habitat creation	♦ Need for land acquisition ♦ Need for capital expenditure to construct the pond ♦ Results in short-term environmental impacts during construction ♦ Results in ongoing maintenance costs ♦ Does not provide any benefit beyond Q_2
2E	***Noel Drive Interceptor*** ♦ Intercept storm sewer outfalls ♦ Remove storm events up to a 2-year return period (Q_2) and convey to regional detention facility at Lougheed Highway ♦ Bypass storm events greater than Q_2 back to Main Stem ♦ Bypass storms less than 0.5 Q_2 back to Main Stem ♦ Design diversion flow = 0.7 cms ♦ Preliminary size selection = 750 mm ϕ ♦ Install in road R/W	♦ Protects/enhances the Main Stem by partially restoring the natural hydrology ♦ Mitigates chronic and/or significant bank erosion and instability in the Main Stem by removing flows that cause 'wear-and-tear'	♦ Need for capital expenditure to construct the piped diversion ♦ Results in short-term environmental impacts during construction ♦ Results in ongoing maintenance costs
3E	***Lougheed Town Centre Area Detention Facility*** ♦ Develop sites on both sides of the Lougheed Highway, and adjacent to Stoney Creek ♦ Required minimum operating storage = 13000 ± m^3 ♦ Size for Q_2 post-redevelopment and release at 0.5 Q_2 for existing development condition	♦ Protects/enhances the Main Stem by partially restoring the natural hydrology ♦ Enables Level 4 to be achieved by mitigating 'changes in hydrology' for existing development ♦ Provides opportunity for water quality improvement ♦ Provides opportunity for habitat creation	♦ Need for land acquisition ♦ Need for capital expenditure to construct the pond ♦ Results in short-term environmental impacts during construction ♦ Results in ongoing maintenance costs ♦ Does not provide any benefit beyond Q_2

7.3 Elements of a Concept Plan for Property Protection

Distinction Between Frequently Occurring and Major Flood Events

Whereas Section 7.2 dealt with the insidious consequences of the *frequently occurring events*, this section deals with the dramatic consequences of the *major flood events*. The distinction between the two conditions is highlighted as follows:

- **Frequently Occurring Events:** These occur 6 to 10 times per year as a result of conversion of forested ground to impervious cover, are rated as minor, and can be mitigated by detention or other BMPs.
- **Major Flood Events:** These are infrequent, typically occur near the end of a period of prolonged wet weather, and are too large to be mitigated by detention.

Even though detention may be provided for the frequent events, the key point to note is that the creek channel and drainage facilities must be still be able to convey Q_{100}.. It must be emphasized that the diversion concept for the Western Sector is based on removing the frequently occurring runoff that would otherwise result in watercourse 'wear-and-tear.'

Assessment of Existing Culvert Installations on Main Stem

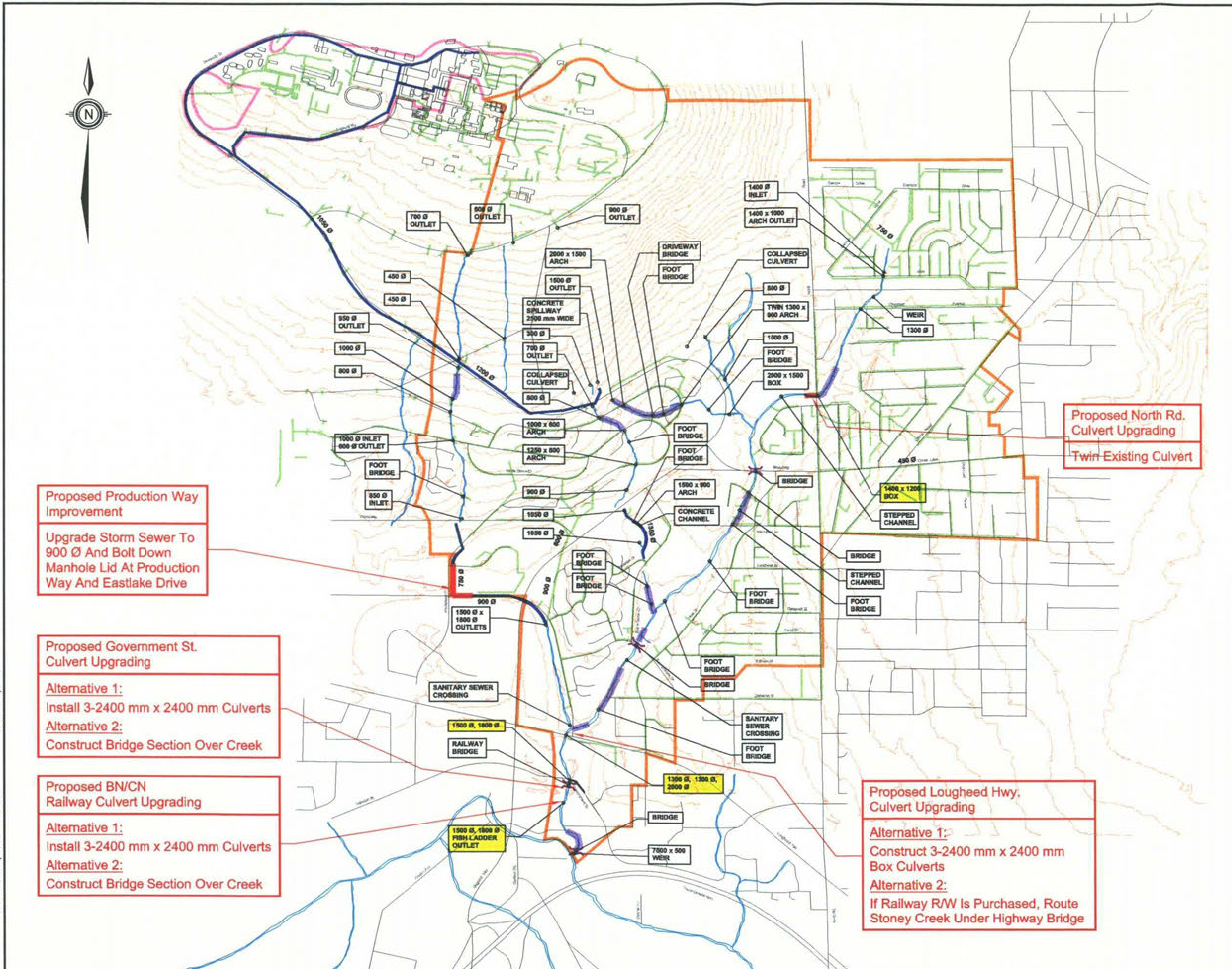
Figure 7-4 presents the *Hydrotechnical Component* of an integrated master drainage plan, and builds on Table 4-2. The latter summarizes the risk assessment described in Chapter 4, and subjectively addresses problems/concerns related to watercourse erosion, hydraulic adequacy, and fish passage at culverts.

Of the six installations along the Main Stem, and based on the *Guidelines for Effective Culvert Design*, all are rated as 'poor' and in need of eventual replacement. Considerations in selecting a time-line for implementation are discussed on the next page.

The GVRD is responsible for maintenance of the Main Stem, with its existing standard for culverts being Q_{25}. As noted in Chapter 4, however, municipalities typically moved from Q_{25} to Q_{100} in the 1970s.

From a risk management perspective, and especially considering the importance of demonstrating due diligence, it may be timely for the GVRD to establish a time-line to achieve compliance with accepted current practice.

It must be emphasized that the computer modelling undertaken as part of this study has generated 'preliminary design flows' for the purposes of an overview-type analysis. For the detailed analysis that should be undertaken as part of a pre-design investigation, however, the model should be both calibrated and verified. The objective would be to ensure a high level of confidence when basing a major capital investment on model output.



LEGEND

- Minor Tributary Area Boundary
- Major Tributary Area Boundary
- Contour In Metres
- Hydraulic Structure Location (And Size)
- Major Watercourses
- Storm Sewer
- Storm Sewer Trunk
- Upgrades - Trunks
- Upgrades - Culverts
- Erosion Sites

KWL CH2M CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

500 0 500
Scale in Metres

PROJECT No.	DATE:
1045-002	Dec. 16, 1998

CONCEPT PLAN FOR FLOOD RISK MANAGEMENT

FIGURE 7-4

1045-002\FIG7-4.DWG Dec.16/98

Time-Line for Main Stem Culvert Replacement Program

The time-line for implementation of culvert replacement is a function of risk and affordability. From a due diligence perspective, having a long-term plan addresses the issue of potential liability should flood damage result from blockage and/or overtopping of a culvert installation that does not meet accepted good practice.

While the GVRD has no record of major flooding problems occurring in the past thirty years, this does not provide assurance that the risks are static or even diminishing. Based on judgement and experience, it may be advisable to make provision for culvert replacements in a 20-Year Capital Plan. Subject to affordability, the timing could always be deferred beyond the 20-year horizon.

Culvert replacement would also enable eventual achievement of environmental objectives by completely eliminating barriers to fish passage, and thereby facilitating access to upstream habitat. From a fisheries perspective, the culvert program could be linked to the strategy and time-line for achieving EIA reduction targets (i.e. the 50-year vision).

In the meantime, it would be desirable to move forward with an ongoing monitoring and data collection program for the purpose of undertaking a full calibration and verification of the Stoney Creek model with concurrent rainfall and runoff data. This would enable refinement of design flow rates and the risk analysis; and facilitate development of an implementation strategy to achieve both hydrotechnical and environmental objectives.

Long-Term Vision for Culvert Replacement on Tributary Channels

Chapter 4 established that culvert installations are generally not 'fish-friendly', but are rated as 'hydraulically acceptable' in terms of being able to pass Q100 (albeit requiring a surcharge). While there is no immediate driving force for a culvert replacement program, this may become desirable over the long-term.

In the interim, and to achieve *Level* 3 objectives, a culvert upgrading/rehabilitation program would be necessary to minimize barriers to fish passage. Identification of site-specific needs and feasibility of implementation is beyond the scope of this study.

Suffice to say that a culvert rehabilitation program should be integrated with an assessment of habitat enhancement opportunities, recognizing that the effectiveness of proposed in-stream measures is dependent on mitigating *changes in hydrology* in the watershed.

Looking well into the future, and to achieve *Level* 4 objectives, a culvert replacement program would be necessary to provide 'bridged' crossings that enable fish migration to upstream habitat that has been recreated through an aggressive program of channel improvements. This would be part of the '50-year vision' once ecosystem protection objectives have been met.

Starting Point for Watercourse Stabilization Program

Figure 7-4 identifies noteworthy erosion sites identified in the course of the creek reconnaissance surveys, and is complemented by the action items identified in Appendix E. The latter provides a checklist that could be applied to develop a channel stabilization program for systematically addressing localized problems.

The action items are generally small-scale, and do not merit bringing forward as recommendations within the context of a macro-planning study.

The focus of an holistic *Watercourse Stabilization Program* would be on preventing the 'unraveling' of the channel as a consequence of the 'wear-and-tear' due to the increased frequency of occurrence of the small runoff events. Hence, the importance of a holistic approach that reflects an understanding of watershed processes as well as creek processes.

The need for engineered in-stream measures may ultimately be tempered if an EIA reduction program is implemented to mitigate the 'changes in hydrology' that provide the trigger for watercourse stability.

Since erosion is an ongoing process, and until an EIA reduction program is in place, it may be desirable for the City of Burnaby to establish an annual budget to deal with site-specific problems as they arise in the Western Sector tributaries. It is understood that the GVRD already has a maintenance budget for the Main Stem.

If Burnaby chooses to include a budget provision for unforeseen maintenance work, then a suggested minimum amount might be in the order of $25,000. This should be adequate to deal with one or two sites per year as and when an urgent need is identified to take remedial action.

Integration with Habitat Enhancement Program

Chapter 5 included a discussion on the effectiveness of habitat enhancement programs in an urban environment. Until watershed issues are addressed through an EIA-reduction program, habitat enhancement efforts should be considered primarily an educational activity.

The 50-year vision would be to develop and implement a comprehensive and integrated program for acquiring additional riparian corridor width and re-creating physical habitat in conjunction with watercourse stabilization and culvert upgrading.

Upsizing of Trunk Sewers

Figure 7-4 identifies one trunk sewer system in Burnaby that should be upsized to resolve capacity and/or surcharging concerns. In other systems, surcharging is deemed to be acceptable.

TABLE 7-4

PRELIMINARY CAPITAL COST ESTIMATES FOR FLOOD AND ENVIRONMENTAL RISK MANAGEMENT

PLAN FOR ENVIRONMENTAL RISK MANAGEMENT

NO.	DESCRIPTION	CLASS D ESTIMATE❶ ($ million)
Western Sector		
1.	Gagliardi Way Phase 1 Diversion (1200 mm Ø)	1.0 ±
2.	Gagliardi Way Phase 2 diversion (1500 mm Ø)	2.5 ±
3.	Western Sector Detention Facility (volume = 15,000 ± m^3)❷❸	3.0 ±
4.	Burlington Northern R/W Detention (volume = 5000 ± m^3)❷❸❹	1.0 ±
	Total for Western Sector (excluding Item #4)	6.50
Eastern Sector		
5.	Pond for Coquitlam/Port Moody tributary Area (volume = 26,000 ± m^3)❷❸	4.0 ±
6.	Pond for Lougheed Town Centre Area (volume = 13,000 ± m^3)❷❸	2.0 ±
7.	Noel Drive Diversion	2.0 ±
	Total for Eastern Sector	8.0 ±
	Grand Total for Both Sectors	14.5 ±

PLAN FOR FLOOD RISK MANAGEMENT

NO.	DESCRIPTION	CLASS D ESTIMATE❶ ($ million)
Culvert Installations		
8.	Lougheed Highway Culvert Replacement	2.0 ±
9.	Government Road Culvert Replacement	1.0 ±
10.	BN/CN Railway Culvert Replacement	2.0 ±
11.	North Road Culvert Replacement	0.5 ±
	Total for Culverts	5.5 ±
12.	Storm Sewer Upsizing on Production Way	0.6 ±
	Grand Total for Both Flood Risk Components	6.1 ±

❶ By definition, a Class D Estimate reflects the application of judgement and experience to generate order-of-magnitude costs (i.e. for assessing affordability and willingness to pay).

❷ Excludes cost of land acquisition, and cost of contaminated site remediation (if required).

❸ Based on experience in other jurisdictions, and for detention facilities having comparable capital costs, the total overall O&M (Operations and Maintenance) cost would be expected to be in the range of 2% to 3% of the capital cost.

❹ Cost for Burlington R/W Detention included for purposes of comparison with the alternative strategy of routing stormwater to the Western Sector Detention Facility.

7.4 Capital Cost Implications for Drainage System Improvements

Table 7-4 presents Class D cost estimates for both the hydrotechnical and environmental components of an integrated master drainage plan. Key points with respect to each component are summarized as follows:

- **Flood Risk Management:** The cost to implement a phased program for culvert replacement (to systematically resolve problems/concerns related to watercourse erosion, hydraulic adequacy, and fish passage) on the Main Stem would be in the order of $5½ million. Refinement of the design storms based on a calibrated model may result in a lowering of this cost. The separate cost for storm sewer upsizing would be $0.6 million.

- **Environmental Risk Management:** The cost to implement regional systems in both the Eastern and Western Sectors (to protect stream corridor ecosystems from being impacted by the frequently occurring storms) would be in the order of $14½ million. This is almost triple the cost of the flood management component.

The purpose of a Class D Estimate is to provide a starting point for decision-making by applying judgement and experience to generate order-of-magnitude data. The accuracy of a Class D Estimate is 25%.

The flood management component could be implemented at any time because the culvert rehabilitation/replacement program is to a large extent independent of the environmental management component. The latter requires a political will on the part of local government to venture into uncharted territory (i.e. a *Level 4 MDP*) to spend scarce resources on protection of the natural environment, its ecosystems and biological diversity.

7.5 Integration with Brunette Watershed Management Plan

The goals and objectives for the *Brunette Watershed Management Plan* provide the over-arching framework for stormwater management in the creek systems that are tributary to the Brunette River. The plan is an evolving document, the final form of which will undoubtedly be significantly influenced by the Stoney Creek process.

Further to the above, the focus of the Stoney Creek process is on determining *how* to achieve the goals and objectives for integrated watershed management as articulated through the Brunette process. To that end, this report has crystallized a drainage planning philosophy, established hydrologic design criteria, identified the elements of a drainage plan, and generated cost estimates.

The 'Stoney Creek model' can now be applied to other tributary creeks within the Brunette system. The objective would be to quantify the total financial exposure of each municipality in fully embracing stream stewardship.

7.6 Summary of Findings

A Synopsis

This chapter describes *how* to integrate 'environmental risk management' with master drainage planning....in order to achieve the stewardship goal of 'holding the line' (i.e. *Level* 3) and over time progressively 'improving conditions' (i.e. *Level* 4) from an ecosystem protection perspective.

Achieving this goal is separate from 'flood risk management', the focus of which is to ensure that the channel system and culvert/bridge installations have adequate hydraulic capacity to convey the 'design flood' (Q^{100}).

In capturing the essence of this Chapter, and in order to conceptualize the decision-making process, this summary of findings relates to *MDP Levels* to a series of incremental choices that in effect provide a visual road map: *Status Quo, Go Part Way,* and *Go All the Way.*

Alternatives for Environmental Risk Management in the Western Sector

A fundamental assumption is that proposed residential development at SFU will be self-mitigating from a stormwater management perspective. However, the feasibility of achieving this goal requires further analysis that incorporates the results of this study. Assuming *changes in hydrology* cannot be mitigated on-site, then the City of Burnaby essentially has three choices for the Western Sector:

- **Status Quo (Level 2):** Do nothing more than continue current practices.
- **Go Part Way (Level 3):** Bypass flow from Tributary #3 into Tributary #1.
- **Go All the Way (Level 4):** Construct a regional detention pond at the Brunette.

The cost to 'go all the way' could be in the order of $6½ million. The benefits are not as easily quantifiable in dollar terms. Hence, it may require a leap of faith to make this level of investment in ecosystem protection.

Alternatives for Environmental Risk Management in the Eastern Sector

Similarly, an inter-municipal approach for the Eastern Sector would be based on these three choices:

- **Status Quo (Level 2):** Do nothing more than continue current practices.
- **Go Part Way (Level 3):** Implement source controls at time of redevelopment.
- **Go All the Way (Level 4):** Construct regional ponds at two locations.

The cost to 'go all the way' could be in the order of another $8 million. Again, a challenge is to quantify the benefits in dollars.

CHAPTER 8

SUMMARY AND RECOMMENDATIONS

8.0 SUMMARY AND RECOMMENDATIONS

8.1 Background

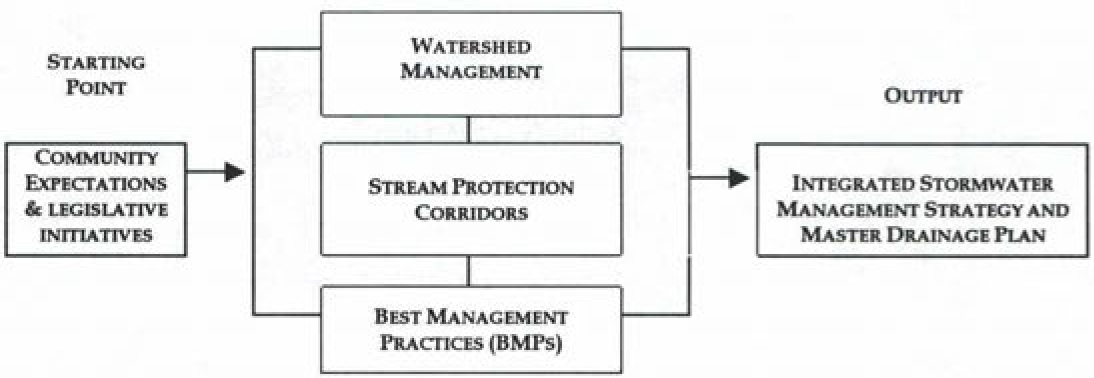
The Environmental Component of a Stormwater Management Strategy

The overall goal in undertaking this study is to identify guiding principles for an integrated approach to stormwater and natural resource management in the Stoney Creek Watershed. The study process therefore involves demonstrating the linkage between stormwater quantity and environmental quality issues, and paving the way for change in terms of the way urban runoff is managed.

This chapter highlights relevant findings from the preceding chapters, and presents an *Action Plan* that will help the City achieve the community vision (as articulated in the Brunette Watershed Municipal Plan) for preservation of the environment and natural beauty of the watershed.

Overview of the Environmental Planning Process

The following diagram is presented for a second time in this report because it is fundamental to conceptualizing the 'building blocks' that provide the foundation for development of a policy on environmental protection that is keyed to an ecosystem-based *Integrated Stormwater Management Strategy*.



A defining question for the environmental planning process is this: How can the ecological values of the Stoney Creek system and the Brunette River be protected and enhanced, while at the same time the City is facilitating land development and/or redevelopment? The objective is to identify *appropriate BMPs* to suit Stoney Creek conditions.

8.2 Framework for Integrated Stormwater Management

Developing an Integrated Master Plan

The goal of the master planning process in the 1990s is to develop an *Integrated Stormwater Management Strategy* that is hydrotechnically sound, environmentally sensitive, and fiscally responsible in protecting property while sustaining natural systems and accommodating growth. Achieving this goal requires an integrated approach to master planning that addresses the following issues:

- classification of watercourses based on fisheries values;
- minimizing the impact of upstream development on receiving waters;
- alleviation of existing drainage, erosion and flooding concerns;
- remediation of existing and/or potential water quality problem areas; and
- protection of major streamside resources.

Understanding the relationship between watershed impervious percentage, watercourse stability, and aquatic abundance and diversity is fundamental to developing a comprehensive stormwater management strategy that is achievable, cost-effective, and supported by the public.

Assessment of Management Objectives

The previously introduced Figure 2-5 provides a sound basis for conceptualizing whether hydrotechnical solutions are also environmentally and politically acceptable. The concept of *MDP Levels* facilitates the process of defining a guiding philosophy by illustrating the consequences for stream corridor ecology as a function of stormwater management objectives.

Components of an Integrated Master Plan

An *Integrated Stormwater Management Strategy* considers all the events that comprise the annual runoff hydrograph, and addresses the spectrum of runoff impacts as follows:

Component	Management Objective	Design Condition	Type of Impact
Hydrotechnical	Protect Property	Extreme Storms	Dramatic
Environmental	Protect Ecosystems	Frequent Storms	Insidious

Until recently, the approach to stormwater management in British Columbia has been shaped by a *Level 2* philosophy. The primary focus has been on the hydrotechnical component. The focus in moving to *Level* 3 is to assess the potential effectiveness of management strategies keyed to impervious area reduction and construction of detention facilities to serve an 'environmental function'

8.3 Protection of the Ecological Function

A Framework for Decision-Making

In the 1990s, the expectations and demands of the public have triggered the need for a 'big picture' approach to ensure that hydrotechnical solutions are also environmentally acceptable. At the same time, the planning framework for *integrated stormwater and natural resource management* should address these fundamental questions:

- What level of aquatic resource protection is achievable/sustainable, and which elements of stream stewardship are applicable?
- What is the municipal liability and financial exposure in embracing senior government directives for protection/enhancement of aquatic habitat?
- Would the societal benefits justify the costs incurred? (i.e., Is there a payback?)

An important first step in the environmental planning process is to understand the cost implications of what it means to embrace a guiding philosophy that places a high priority on protecting fish and related stream corridor ecology.

Making Stream Stewardship A Reality

Dealing with the fish protection issue requires a clear definition of a community's goals, and in so doing raises a host of questions, including:

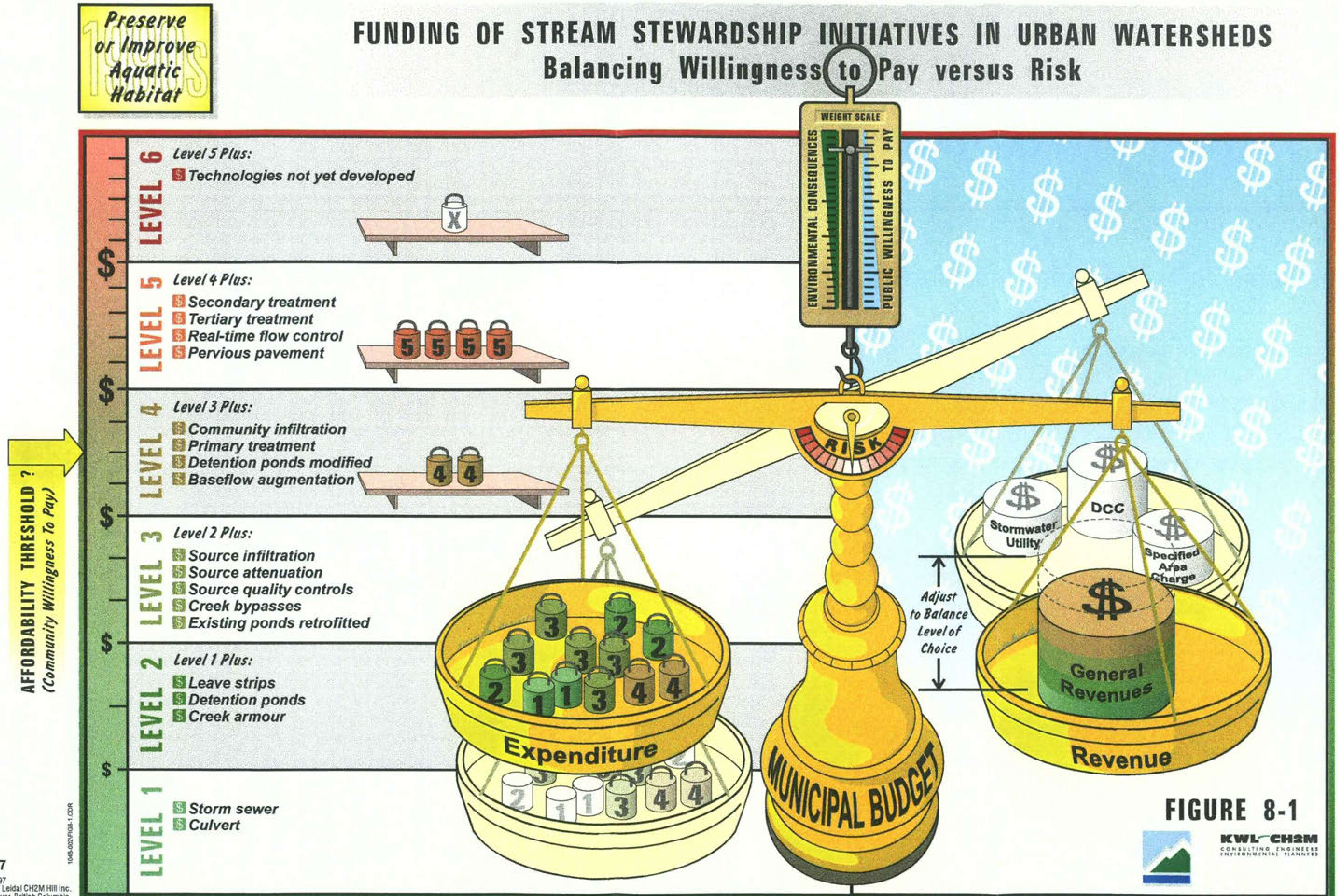
- What is the diversity and abundance of fish in a creek system?
- What must be protected to maintain the diversity and abundance?
- Are there opportunities to enhance/restore fish populations?
- What will it cost?

Addressing these questions up front will enable the municipality to judge what level of stream stewardship is achievable and sustainable at an affordable cost.

Funding An Integrated Master Plan

The concept (as presented in Chapter 2) of defining *MDP Levels* is a first. This results in a unique set of challenges in quantifying the cost implications in moving from *Level* 2 to a *Level 3* or *Level 4* master plan as illustrated on Figure 2-5.

Figure 8-1 integrates Table 1-2 and Figure 2-5 in posing this question: *How does a municipality pay for integrated stormwater and natural resource management*? The question has two aspects. On the one hand, there is the need to generate revenue to balance expenditures. On the other hand, there is the issue of risk when optimizing willingness to pay versus environmental consequences. These issues need to be communicated to the public when building understanding and support for a funding plan.



Preserve or Improve Aquatic Habitat
FUNDING OF STREAM STEWARDSHIP INITIATIVES IN URBAN WATERSHEDS
Balancing Willingness to Pay versus Risk
WEIGHT SCALE
ENVIRONMENTAL CONSEQUENCES
PUBLIC WILLINGNESS TO PAY
LEVEL 6
Level 5 Plus:
Technologies not yet developed
LEVEL 5
Level 4 Plus:
Secondary treatment
Tertiary treatment
Real-time flow control
Pervious pavement
LEVEL 4
Level 3 Plus:
Community infiltration
Primary treatment
Detention ponds modified
Baseflow augmentation
LEVEL 3
Level 2 Plus:
Source infiltration
Source attenuation
Source quality controls
Creek bypasses
Existing ponds retrofitted
LEVEL 2
Level 1 Plus:
Leave strips
Detention ponds
Creek armour
LEVEL 1
Storm sewer
Culvert
AFFORDABILITY THRESHOLD ?
(Community Willingness To Pay)
RISK
Expenditure
MUNICIPAL BUDGET
Revenue
Stormwater Utility
DCC
Specified Area Charge
General Revenues
Adjust to Balance Level of Choice
KWL CH2M
CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS
1045-002\FIG8-1.CDR

FIGURE 8-1

8.4 Conclusions

The purpose of this section is to draw some conclusions that set the stage for the recommendations that follow in the next section:

Integrated Master Planning and Stormwater Management

1. **Framework for Integrated Stormwater Management:** The *Brunette Basin Watershed Management Plan* provides an over-arching framework for the Stoney Creek process, with the goal being development of a master drainage plan for the Stoney Creek watershed that protects property and allows economic land use while sustaining natural systems.

2. **Decision-Making Tool for Master Drainage Planning:** The concept of *MDP Levels* facilitates the process of defining a guiding philosophy by illustrating the consequences for stream corridor ecology as a function of stormwater management objectives, and providing a sound basis for conceptualizing whether hydrotechnical solutions are also environmentally and politically acceptable

3. **Flood Risk Management versus Environmental Risk Management:** The purpose of *flood risk management* is to protect property by ensuring that the 'design flood' can be contained by creek channels and passed by culverts; whereas the purpose of *environmental risk management* is to protect stream corridor ecosystems from being degraded by the insidious consequences of frequently occurring small storms.

4. **Consequences of Changes in Hydrology:** Replacement of native ground cover with impervious surfaces results in an increased frequency of occurrence of threshold levels of runoff from 'small storms', and this in turn triggers watercourse erosion and sedimentation processes that then degrade or eliminate aquatic/riparian habitat.

5. **Existing Percentage of Total Impervious Area (TIA):** The fraction of the Stoney Creek watershed covered by constructed, non-infiltrating surfaces (such as concrete, asphalt and buildings) is 29%.

6. **Total versus Effective Impervious Area (EIA):** EIA is defined as the impervious surfaces with direct hydraulic connection to the downstream drainage (or stream) system, and therefore excludes some paved surfaces that may contribute nothing to the storm-runoff response of the downstream system.

7. **Sizing Stormwater Detention Facilities:** Establish storage volumes by applying the Q_2 input hydrograph to developed catchments and Q_5 to undeveloped catchments, and releasing at 0.5 Q_2 (for the 'existing' development condition) to mitigate the *frequently occurring storms*.

Table 8-1: Decision Criteria to Select Strategies for Stream Management

NO.	OBJECTIVES OR DECISION CRITERIA AS ESTABLISHED BY THE BRUNETTE BASIN TASK GROUP	HOW IMPORTANT IS EACH DECISION CRITERION?❶	HOW WELL DOES EACH SCENARIO ACHIEVE EACH OBJECTIVE?❷ SCENARIO A (LEVEL 2 MDP) STATUS QUO, CONTINUED DECLINES IN FISH*	SCENARIO B LEVEL 3 MDP) HOLD THE LINE, SUSTAIN TROUT AND HATCHERY SALMON*	SCENARIO C (LEVEL 4 MDP) STRATEGY C: ENHANCE HABITAT, SUSTAIN WILD SALMON*
1.	Protect or enhance biodiversity*	very important	low	medium	high
2.	Protect or enhance aquatic habitat*	very important	low	medium	high
3.	Protect or enhance terrestrial habitat	moderate importance	low	medium	high
4.	Enhance recreation opportunities	moderate importance	low	medium	high
5.	Minimize health and safety impacts	very important	high	high	high
6.	Minimize total costs❸	very important	high (no change in existing costs)	medium (increased costs)	low (high cost)
7.	Minimize property damage	very important	medium	high	high
8.	Increase scientific and management understanding	least important	medium	high	high
9.	Increase opportunity for public learning	least important	medium	high	high

* See Tables 3-1, 3-2 and 3-3 for refinement of these Decision Criteria and for more detailed descriptions of the scenarios.

❶ Based on the experience of the project team, three judgemental choices are provided for rating each objective: very important, moderate importance, and least important.

❷ Based on the experience of the Project Team, three judgemental choices are provided for rating each scenario: low, medium and high.

❸ By definition "total costs" are based on present value analysis.

Conceptual Framework for Decision Process

8. **Six-Step Process for Making and Implementing Decisions**: The Steering Committee has arrived at *Step Five* which involves selection of preferred alternatives; with the final step being development of an Implementation Plan once the political leadership of each partner municipality verifies its' commitment to 'making something happen.'

9. **Application of Decision Criteria:** Table 8-1 is a matrix that provides the philosophical underpinning for moving in a direction that is keyed to 'holding the line' as an immediate minimum goal, and 'improving conditions' over time as an ultimate goal, by relating three scenarios (for varying levels of environmental protection) to the set of nine objectives established by the *Brunette Basin Watershed Management Plan*

10. **Optimizing Willingness to Pay versus Environmental Consequences:** Given that Objective #6 (Minimize Total Costs) in Table 8-1 may effectively offset the other eight, a challenge is to build understanding and support among the public for a funding plan that is keyed to *environmental risk management* (Note: the benefits of which are difficult to quantify in dollar terms)

Results of Drainage Facility Assessment

11. **Hydraulic Adequacy and Risk Assessment for Culvert Installations**: The majority of the 18 existing culvert installations on the Main Stem and tributaries are undersized for Q_{100} (i.e. the '100-year design flood'), and are rated as 'high risk' in terms of vulnerability to blockage.

12. **Floodway Capacity of Main Stem:** The floodway that defines the Main Stem has adequate hydraulic capacity to contain Q_{100}.

13. **Conveyance Capacity of Storm Sewer Network:** System surcharging in some areas combined with a limited program of storm sewer upsizing would be sufficient to handle Q_{10}, especially if system capacity has been adequate to handle even the major storms of record.

14. **Starting Point for Watercourse Stabilization Program:** Observations noted during watercourse reconnaissance surveys provide a basis for development of a maintenance program to stabilize critical sections of the channel system, including application of bioengineering techniques as an alternative to conventional rip-rap.

15. **Hydrometric Data Collection for Calibrated Modelling:** Although a 'validated' computer model has been applied to generate 'preliminary design flows' for the purposes of an overview-type analysis, an important next step is to both calibrate and verify the model as part of the pre-design investigation leading to development of an implementation strategy for a culvert replacement program.

Results of Aquatic Habitat Assessment

16. **Condition of Stoney Creek Stream Corridors:** Although the Main Stem has been noticeably subjected to erosion for about one-quarter of its length, the watershed supports an ecosystem that is vital to the fish and wildlife resources of the Brunette Basin.

17. **Assessment of Fisheries Productivity:** The Stoney Creek ecosystem supports spawning and rearing populations of coho and steelhead trout, as well as resident and sea-run cutthroat trout; with the presence of steelhead and anadromous cutthroat trout being particularly significant because of their rare occurrence in urban streams.

18. **Correlation of Impervious Area with Stream Corridor Health:** The overall TIA (Total Impervious Area) is presently about 29%, which is close to the threshold level of 30% to 35% where the changes in hydrology are usually so significant that most urban watersheds may be unable to sustain *abundant self-supporting* populations of cold water fish.

19. **Identification of Best Habitat Values:** The 'highest value reach' is the on the Main Stem between the Lougheed Highway and the confluence with the Brunette River; with the 'next best reach' being Tributary #3.

20. **Implications for Watershed Planning Process:** The stormwater management strategy needs to protect the two best sections of creek from further *changes in hydrology;* and enable conditions to be improved in the Main Stem above Lougheed (i.e. the section that has been noticeably impacted).

21. **Environmental Health of Stream Corridors:** An ambient biological assessment methodology that is gaining recognition in the Pacific Northwest for environmental monitoring is the *Benthic Index of Biotic Integrity* (B-IBI) because it consistently correlates well with urbanization, and is sensitive to slight change.

Results of Runoff Quality Monitoring

22. **Results of Baseflow Water Quality Monitoring:** The most significant finding is that nutrient concentrations (Nitrate-N) were somewhat high for this type of urban watershed, underscoring the need for a possible source control program related to seasonal use of fertilizers.

23. **Results of Storm Event Water Quality Monitoring:** Continuous turbidity monitoring shows that turbidity responds quickly to increasing flow, particularly at the beginning of the event, and that turbidity is primarily caused by urban runoff rather than by stream-bed erosion.

24. **Impact of Turbidity on Fish Health:** The stress effect on fish is a function of the duration of exposure and the concentration of suspended sediment; even during a record storm event on May 24th1998, both duration and concentration were below the levels that result in sub-lethal effects.

25. **Relationship Between Turbidity and TSS (Total Suspended Solids):** Based on correlation of field measurements and laboratory analyses has enabled development of an equation that can be used to derive suspended solids data from simple turbidity measurements.

26. **Customizing a BMP Strategy for Runoff Quality Control**: The initial effort should be invested in public education, maintenance programs, and source control regulations; plus provision should be made for spill containment at high risk locations.

27. **Regulation of Impervious Area:** Recent amendments to the Muncipal Act provide the partner municipalities with the enabling tools to maintain and/or reduce the overall percentage of impervious surface cover; therefore, the partner municipalities do have the opportunity to use EIA as a performance measure for 'holding the line' (Level 3 MDP) and 'improving conditions' (Level 4 MDP).

Concept Planning for Integrated Stormwater Management

28. **Culvert Replacement and Storm Sewer Upsizing Program:** The $5½ million flood management component of a master drainage plan could be implemented at any time within the next 20 years because the proposed program is for the most part independent of the program for ecosystem enhancement.

29. **Acceptance of the Strategy for Environmental Risk Management:** Before anything can happen in terms of 'holding the line' (Level 3) and over time 'improving conditions' (Level 4) in Stoney Creek, there needs to be a political will to make something happen.

30. **Stormwater Management Strategy for Simon Fraser University:** If detention and impervious area reduction to 'hold the line' (Level 3) are not fully achievable on-site for either physical or economic reasons, then the fallback strategy is to contribute to funding of an off-site regional system.

31. **Capital Cost Implications for a Level 4 Regional System:** The total off-site cost would be at least $14½ million to construct regional diversion and storage facilities to protect stream corridor ecosystems from being impacted by the *frequently occurring storms.*

Finally, Table 7-1 is a key deliverable because it addresses the four major factors limiting the environmental values of urban streams. Furthermore, it presents a framework for action to achieve the Brunette Vision for a sustainable environment.

8.5 Recommendations

This section presents an *Action Plan* that flows from the conclusions presented in the previous section. The objective is to provide a clear picture of what needs to be done to advance a comprehensive stormwater management strategy that is achievable, cost-effective, and supported by the public. There are four 'core' recommendations:

1. **Framework for Watershed Management:** Adopt-in-principle the comprehensive and integrated framework as presented in Table B that defines MDP Levels for ecosystem protection and enhancement in the Stoney Creek watershed.
2. **Component Plan for Environmental Risk Management:** Complete detailed investigations to verify the costs and assess the feasibility of implementing the plan as presented on Figure 7-1 to protect stream corridor ecosystems from being impacted by the frequently occurring 'small storms.'
3. **Component Plan for Flood Risk Management:** Adopt the plan as presented on Figure 7-4 for culvert rehabilitation and/or replacement to systematically resolve problems/concerns related to watercourse erosion, hydraulic adequacy and fish passage.
4. **EIA (Effective Impervious Area) as a Performance Measure:** Require impervious area reduction measures in redevelopment or new development areas to 'hold the line' at the existing 23% level for the watershed, and over time reduce the EIA to below 20% to 'improve conditions'.

Ancillary recommendations that flow from the above core recommendations total fifteen, with the first four being key to moving forward with development of an Implementation Plan. They are highlighted separately because they reflect the political process:

1A. Endorsement by Municipal Councils: Make presentations to the three municipal Councils (i.e. Burnaby, Coquitlam and Port Moody) to obtain endorsement-in-principle for the four core recommendations (i.e. Step Five in the *Six-Step Process* for making and implementing quality decisions).

1B. Public Information Program: Raise community awareness of (and build support for) the direction in which the inter-municipal partnership for integrated stormwater management is heading, by publicizing the Stoney Creek findings through the Brunette Basin communication channels

1C. Environmental Agencies: Reach consensus with the Ministry of Environment and Federal Fisheries regarding achievable goals and expectations for 'improving conditions' over time, and for applying EIA as a performance measure.

1D. Roles and Responsibilities: Align the efforts of the GVRD, partner municipalities and municipal departments to achieve the shared vision for watershed and stream corridor management.

The next eleven action items reflect the need for an increasing level of detail to provide direction for the Implementation Plan that would be developed by municipal staffs following endorsement by the municipal Councils of the core recommendations:

No.	Issue and Recommendation
2A.	**Habitat Enhancement Program:** Use Table 5-1 as a checklist to develop a comprehensive program in conjunction with watercourse stabilization and where upgrading to systematically improve aquatic habitat conditions in the channel system.
2B.	**Greenway Restoration:** Revegetate riparian corridors and realign trail systems to be 'fish-friendly' while at the same time accommodating human needs.
2C.	**Runoff Quality Control:** Invest in public education, maintenance management programs, and source control regulations; and provide for spill containment at high risk locations.
2D.	**Environmental Health of Stream Corridors:** Implement baseline ambient monitoring of a *Benthic Index of Biotic Indicators (IB-IBI)* as part of an integrated program for monitoring stream corridor health..
3A.	**Watercourse Stabilization Program:** Develop a comprehensive channel maintenance program for systematically addressing localized problems that require remedial action.
3B.	**Culvert Replacement Program for Main Stem**: Undertake pre-design investigations (complete with calibrated hydrologic modelling) to properly analyze the acceptability/feasibility, implementation details and cost of replacing the culvert installations at North Road, Lougheed, Government, and the CN/BN right-of-way.
4A.	**Calibrated Computer Model:** Establish an ongoing monitoring and data collection program, undertake a full calibration of the Stoney Creek model with concurrent rainfall and runoff data, and use the model as a monitoring tool to periodically verify the EIA.
4B.	**Criteria for Detention Facility Sizing:** Adopt the criteria as presented in this report for estimating storage volumes and establishing release rates.
4C.	**Sites for Regional Stormwater Detention:** Confirm the feasibility of site development and secure/reserve the three sites identified in this report for possible future construction of regional detention ponds.
4D.	**New Development at Simon Fraser University:** Provide on-site stormwater management measures to reduce post-development impact on runoff, and to meet Level 3 objectives as a minimum.
4E.	**Long-Term Effectiveness of Management Strategy:** Establish a GVRD/Inter-municipal protocol agreement for ensuring that the effectiveness of strategy implementation is re-evaluated at 5-year intervals.

Implementation of these recommendations will protect the Stoney Creek ecosystem, accommodate growth, and ultimately provide additional benefits (e.g. open space, trail corridors and public education).

APPENDIX A

DOCUMENTATION FOR HYDROLOGY WORKING SESSION

KWL-CH2M

Kerr Wood Leidal-CH2M Hill Inc.
139 West 16th Street, North Vancouver
British Columbia, Canada V7M 1T3
TEL: 604.985.5361
FAX: 604.985.3705 EMAIL: kwl@kwl.bc.ca

CONSULTING
ENGINEERS
ENVIRONMENTAL
PLANNERS

MEMORANDUM

DATE: May 11, 1998

TO: Lambert Chu, P.Eng., Chairman
Stoney Creek Stormwater Management Steering Committee

CC: Bill Derry, Senior Consultant
Ron Kistritz, Aquatic Ecologist

FROM: Kim Stephens, M.Eng., P.Eng., Project Manager
Chris Johnston, P.Eng., Project Engineer

RE: **STONEY CREEK STORMWATER MANAGEMENT PLAN**
Agenda for Hydrology Working Session
Our File No. 1045.002A

Attached is a proposed agenda to guide the discussion on May 11th, and to ensure that we are time-effective in facilitating information transfer during the 2-hour working session. Also attached is a copy of the "pink handout" from our April 22nd working session with the Steering Committee.

A fundamental point to note is that an *Integrated Stormwater Management Strategy* considers all the rainfall events that comprise the annual runoff hydrograph, and comprises two distinct components:

Component	Management Objective	Hydrotechnical Focus	Type of Impact
Hydrotechnical	Protect Property	Infrequently Occurring Large Storms	Dramatic (flood and erosion damage resulting from peak flows)
Environmental (Enhanced Hydrotechnical)	Protect Ecosystems	Frequently Occurring Small Storms	Insidious (water quality deterioration, watercourse erosion and sedimentation resulting from the increased number of runoff events per year)

The focus of the *Hydrology Working Session* will be on the "environmental component," and the implications in customizing engineering criteria to achieve the goals and objectives for the different *MDP Levels*.

KAS/sj
Encl.

T:\1045-002.A\CORRESP\AGENDA

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Agenda for Hydrology Working Session on May 11, 1998

ITEM	TIME	TOPIC AND BRIEFING NOTES
1	2:00 - 2:15	**Purpose of Working Session** ▸ Distinguish between infrequently occurring major events and frequently occurring small storms. ▸ Focus of session is on sharing the experience of other municipalities. ▸ Review handout titled *Aquatic Habitat Assessment and Implications for Management Strategies* for background on the impacts of changes in hydrology.
2	2:15 - 3:00	**Results of Analysis for a Typical Year** ▸ Discuss Figure 2-2 which illustrates watershed response in a "typical rainfall year" for a range of land-use conditions. ▸ Review the data collection effort that underpins the scientific basis for Figure 2-2. ▸ Assess the implications of a flow distribution analysis that correlates the changes in the number of erosion-causing events in a typical year.
3	3:00 - 3:45	**Design Criteria for Sizing Detention Facilities** ▸ Introduce extracts from the Puget Sound Manual. ▸ Review Table A which summarizes volume requirements as a function of release rate and land-use condition. ▸ Discuss how the objectives of either a *Level 3* or *Level 4* MDP can be achieved.
4	3:45 - 4:00	**Application to Stoney Creek Stormwater Management Plan** ▸ Recognize that the effectiveness of detention ponds limited to mitigation of the frequently occurring storms (i.e. smaller than Q2). ▸ Embrace the concept of MDP levels for sizing ponds as a function of release rate criteria. ▸ Select an *MDP Level* after the analysis is completed to assess the achievability of the management objectives.

AQUATIC HABITAT ASSESSMENT AND IMPLICATIONS FOR MANAGEMENT STRATEGIES
(Applying the Experience of Other Municipalities)

The Issue: Watercourse erosion resulting from changes in hydrology.

Changes in hydrology remove fish habitat and result in loss of biodiversity and abundance.

The Goal: Develop a strategy for ensuring the *environmental health* of major streamside resources by addressing the *changes in hydrology*.

How: Build on a hydrotechnical foundation that considers all runoff events comprising the annual hydrograph.

Apply the experience of other municipalities that have made major investments in hydrometric data collection and/or environmental monitoring programs.

Findings: Having solid data eliminates speculation.

Peak rates of runoff for infrequent major events are not significantly changed by land use densification, while peak rates for frequent events are very different.

Watercourse erosion (above "natural" rates) is caused by the increased frequency of occurrence of the *frequent events.*

Channel shape is created by a combination of the frequent events and the Mean Annual Flood (note: increases in magnitude with urbanization).

Approach: Focus on the *changes in hydrology* that have resulted from land use changes.

Resolve the erosion issue and a spinoff benefit will be fish habitat protection.

Strategy: Design detention facilities to mitigate the *frequently occurring storms* (i.e. 6 times a year threshold event). If detention is not feasible, and subject to a cost-benefit analysis, bypass peak flows around critical creek sections that have high fisheries values. Alternatively, implement on-site measures to reduce impervious cover.

Detention facilities would serve an "engineering function" to prevent watercourse destabilization. The spinoff benefit in addressing *changes in hydrology* would be preservation of aquatic habitat and pollutant removal (i.e. the "environmental function").

The Key: Being able to relate stormwater management goals to detention criteria (i.e. unit release rates and storage volumes).

AQUATIC HABITAT ASSESSMENT
AND IMPLICATIONS FOR MANAGEMENT STRATEGIES
(Applying the Experience of Other Municipalities)

The Tool: Stormwater management graphics are science-based and conceptualize key concepts. The objective is to develop a common understanding so that a diverse group of stakeholders can make informed decisions regarding what *may* be achievable.

The concept of *MDP (Master Drainage Plan) Levels* facilitates the process of defining a guiding philosophy, and assessing whether hydrotechnical solutions are also environmentally and politically acceptable.

Background: The concept of a hierarchy of *MDP Levels* makes it possible to categorize the evolution of drainage planning philosophy in recent decades.

Until recently, the approach to stormwater management in British Columbia has typically been shaped by a *Level 2* philosophy: Provide detention storage for major events to maintain peak discharge rates at pre-development levels to achieve the basic goal of protecting property.

Achieving the expanded goal of mitigating frequent storms and preserving aquatic habitat requires a minimum of a *Level 3 MDP* for existing developed areas; and a *Level 4 MDP* for new development areas.

The guiding philosophy for a *Level 3 MDP* is summarized as follows: Implement BMPs that mitigate the effects of redevelopment by *at least* maintaining existing conditions in stream corridors so that there will be no further loss of biodiversity and abundance (i.e. "hold the line").

The guiding philosophy for a *Level 4 MDP* is captured as follows: "Make conditions better" in existing developed areas.

Criteria: Selection of appropriate criteria is fundamental to developing a stormwater management plan.

The challenge is customizing engineering criteria to achieve the goals and objectives for the different *MDP Levels.*

The relevant engineering criteria are the input storm, the release rate(s), and the storage volume. (Note: use rules-of-thumb in lieu of continuous simulation.)

Experience: The *Bear Creek MDP* for the City of Surrey is an application of customized criteria to develop different strategies for different land uses (i.e. by "putting numbers to the concepts").

KWL-CH2M

Kerr Wood Leidal-CH2M Hill Inc.
139 West 16th Street, North Vancouver
British Columbia, Canada V7M 1T3
TEL: 604.985.5361
FAX: 604.985.3705 EMAIL: kwl@kwl.bc.ca

CONSULTING
ENGINEERS
ENVIRONMENTAL
PLANNERS

RECORD OF MEETING

DATE OF MEETING: May 11, 1998

LOCATION: Burnaby Engineering

DURATION: 2 p.m. until 4:30 p.m.

ATTENDED BY:

NAME	ORGANIZATION	FAX NO.
Lambert Chu	City of Burnaby	294-7425
Chris Roberts	City of Port Moody	469-4550
Caroline Berka	GVRD	436-6714
Ed Von Euw	GVRD	436-6714
Kim Stephens	KWL-CH2M Hill	985-3705
Chris Johnston	KWL-CH2M Hill	985-3705

CHAIRED BY: Lambert Chu

MINUTES BY: Kim Stephens

SUBJECT: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT PLAN**
Hydrology Working Session
Our File No. 1045-002.A

The purpose of the session was to reach consensus on the selection of engineering criteria for sizing stormwater detention facilities to suit conditions in the Stoney Creek Watershed. The focus of the discussion was on two new 'hydrology graphics' that provide a measurement-based understanding of the implications of *changes in hydrology*. This is an important first step in developing an appropriate and cost-effective stormwater management strategy.

Cont....

Key decisions arising from the discussion are highlighted as follows:

1. The purpose of detention ponds is to mitigate the *frequently occurring storms.*

2. The input design event for developed catchments is to be Q_2.

3. The input design event for undeveloped catchments is to be Q_5.

4. The starting point for assessing the order-of-magnitude for storage volumes is a release rate that corresponds to $0.5Q_2$ (i.e., for the 'existing' development condition).

5. The release rate criterion is to be compared with the 'critical sustainable velocity' for the Stoney Creek channel.

In summary, the concept of *MDP Levels* has been embraced-in-principle for sizing ponds as a function of release rates. However, the selection of an *MDP Level* will be made after the analysis is completed to access the achievability of the stormwater management objectives.

Attached is an updated copy of the table titled *Comparison of Stormwater Detention Requirement for Varying MDP Levels and Goals.* The release rate column has been clarified by adding '50% of Q_2' under each of the criteria.

In closing, we take this opportunity to express an appreciation for the quality of questions and feedback by the workshop participants regarding the content of our presentation. It was an enjoyable and productive working session. It has also provided us with direction in moving forward with the master planning process.

KAS/am

T:\1045-002.A\CORRESP\MAY11ROM.WPD

:OMPARISON OF STORMWATER DETENTION RE' IREMENTS FOR VARYING MDP LEVELS AND GO/

MDP Level	Input Design Event	Release Rate Criteria	Detention Volume for Various Tributary Land Uses (m^3/ha)		
			40% Impervious	60% Impervious	80% Impervious
Level 4 *Improve Habitat*	24- Hour 2 Year	Natural Forested (50% of Q_2)	340	365	415
	24- Hour 5 Year	Natural Forested (50% of Q_2)	520	550	575
Level 3 *Hold The Line*	24- Hour 2 Year	Single Family Post Dev (50% of Q_2)	170	200	240
	24- Hour 5 Year	Single Family Post Dev (50% of Q_2)	305	335	375
Level 2+ *Interim Standard*	24- Hour 5 Year	50% of Post Dev Q_2	215	170	145

- Detention volumes based on design storm simulation with calibrated model parameters, 1.5m maximum pond depth, 1V:4H side slopes, single orifice outlet configuration.
- Volumes are live storage only: no allowance for overflow, freeboard, landscaping, or setbacks is made.

MDP Level	Input Design Event	Release Rate Criteria	Fraction of Tributary Land Area Required for Live Storage Shown Above		
			40% Impervious	60% Impervious	80% Impervious
Level 4 *Improve Habitat*	24- Hour 2 Year	Natural Forested (50% of Q_2)	2.5 %	2.6 %	3.0 %
	24- Hour 5 Year	Natural Forested (50% of Q_2)	3.7 %	3.9 %	4.1 %
Level 3 *Hold The Line*	24- Hour 2 Year	Single Family Post Dev (50% of Q_2)	1.3 %	1.5 %	1.8 %
	24- Hour 5 Year	Single Family Post Dev (50% of Q_2)	2.3 %	2.5 %	2.7 %
Level 2+ *Interim Standard*	24- Hour 5 Year	50% of Post Dev Q_2	1.6 %	1.3 %	0.8%

Land fractions are based on volumes (and assumptions) in top table, therefore total land requirements are higher.

Disclaimer: These figures, while based on a real case study, are for illustrative purposes only and should not be used for facility design.

Stormwater Management Manual for the Puget Sound Basin

(The Technical Manual)

Volume I - Minimum Technical Requirements

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

CHAPTER I-2

MINIMUM REQUIREMENTS FOR ALL NEW DEVELOPMENT AND REDEVELOPMENT

I-2.1 INTRODUCTION

The 1991 Puget Sound Water Quality Management Plan (as amended) requires all counties and cities within the Puget Sound drainage basin to adopt ordinances to control runoff from new development and redevelopment by July 1994. The Plan also directs local governments to adopt stormwater programs which include minimum requirements for new development and re-development set by the Plan and in guidance developed by Ecology. These ordinances are to address:

"... at a minimum: (1) the control of off-site water quality and quantity (as related to quality) impacts; (2) the use of source control best management practices and treatment best management practices; (3) the effective treatment, using best management practices of the storm size and frequency (design storm) as specified in the manual for proposed development; (4) the use of infiltration, with appropriate precautions, as the first consideration in stormwater management; (5) the protection of stream channels and wetlands; and (6) erosion and sedimentation control for new construction and re-development projects."

This chapter has been developed in response to the direction in the Plan. The reader is also referred to Volume II of the "Stormwater Program Guidance Manual for the Puget Sound Basin" (hereafter referred to as the Guidance Manual), a companion to this technical manual, which contains a model ordinance that incorporates these Minimum Requirements.

There are several sets of requirements for proposed new development and redevelopment that are applied depending on the type and size of the proposed development. In general, small sites are required to control erosion and sedimentation from construction activities while larger sites must also provide permanent control of stormwater runoff. Sites being redeveloped must generally meet the same minimum requirements as new development sites for the portion of the site being redeveloped. In addition, redevelopment sites must provide source control BMPs for the entire site. There may also be situations in which additional controls are required for sites, regardless of type or size, as a result of basin plans or special water quality concerns.

Development sites are to demonstrate compliance with the Minimum Requirements through the preparation of Stormwater Site Plans (SSP). The plans are described in detail in Chapter I-3 and in the Guidance Manual.

Two major components of these plans are an Erosion and Sediment Control (ESC) Plan and a Permanent Stormwater Quality Control (PSQC) Plan. The ESC plan is intended to be temporary in nature to control pollution generated during the construction phase only, primarily erosion and sediment. The PSQC is intended to provide permanent BMPs for the control of pollution from stormwater runoff after construction has been completed. For small sites, this requirement is met by implementing a Small Parcel Erosion and Sediment Control Plan.

A flow chart demonstrating these requirements is shown in Figure I-2.1.

<u>Definitions</u>:

> **New development - means the following activities: land disturbing activities, structural development, including construction, installation or expansion of a building or other structure; creation of impervious surfaces; Class IV - general forest practices that are conversions from timber land to other uses;**

and subdivision, short subdivision and binding site plans, as defined in Ch.58.17.020 RCW. All other forest practices and commercial agriculture are not considered new development.

Redevelopment - means, on an already developed site, the creation or addition of impervious surfaces, structural development including construction, installation or expansion of a building or other structure, and/or replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities associated with structural or impervious redevelopment.

Impervious surface - means a hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces.

Land disturbing activity - means any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to demolition, construction, clearing, grading, filling and excavation.

Source control BMP - A BMP that is intended to prevent pollutants from entering stormwater. A few examples of source control BMPs are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

Throughout this Chapter, guidance to meet the requirements of the 1991 Puget Sound Water Quality Management Plan (as amended) is written in bold and supplemental guidelines that serve as advice and other materials are not in bold.

I-2.2 EXEMPTIONS

- **Commercial agriculture, and forest practices regulated under Title 222 WAC, except for Class IV General forest practices that are conversions from timber land to other uses, are exempt from the provisions of the minimum requirements. All other new development is subject to the minimum requirements.**

I-2.3 SMALL PARCEL MINIMUM REQUIREMENTS

- **The following new development shall be required to control erosion and sediment during construction, to permanently stabilize soil exposed during construction, to comply with Small Parcel Requirements 1 through 4, and to prepare a Small Parcel Erosion and Sediment Control Plan:**

  (a) Individual, detached, single family residences and duplexes.
  (b) Creation or addition of less than 5,000 square feet of impervious surface area.
  (c) Land disturbing activities of less than one acre.

Objective: The objective of this requirement is to address the cumulative effect of sediment coming from a large number of small sites.

Supplemental Guidelines: Small parcels under 5,000 sq.ft. in size and individual, detached, single family residences and duplexes, require the simplified erosion and sediment controls contained in a Small Parcel Erosion and Sediment Control Plan (SPESC). This plan is required to fulfil the Small Parcel Minimum Requirements outlined below in Section I-2.3. The Small Parcel BMPs found in Section II-5.10 in Volume II are used to develop the plan. A complete description of a Small Parcel ESC Plan can be found in Section I-3.3. The SPESC plan is meant to be temporary in nature to deal with erosion and sediment generated during the construction phase only. Local governments may choose to apply additional permanent, site-specific stormwater controls to small parcels.

One method of proof of compliance could be the use of a checklist similar to that found in Figure I-3.1. This list can be adapted as necessary to include individual requirements of a local government.

SMALL PARCEL REQUIREMENT #1 Construction Access Route

- **Construction vehicle access shall be, whenever possible, limited to one route. Access points shall be stabilized with quarry spall or crushed rock to minimize the tracking of sediment onto public roads.**

Supplemental Guidelines: If sediment is inadvertently transported onto public roads, roads shall be cleaned thoroughly at the end of the day by shoveling or sweeping. Street washing should only be done after the bulk of the sediment has been removed by sweeping.

SMALL PARCEL REQUIREMENT #2 Stabilization of Denuded Areas

- **Soil stabilization. All exposed and unworked soils shall be stabilized by suitable application of BMPs, including but not limited to sod or other vegetation, plastic covering, mulching, or application of ground base on areas to be paved. All BMPs shall be selected, designed and maintained in accordance with an approved manual. From October 1 through April 30, no soils shall remain exposed for more than 2 days. From May 1 through September 30, no soils shall remain exposed for more than 7 days.**

Supplemental Guidelines: BMPs should be selected which are appropriate for the time of the year and anticipated duration of use.

SMALL PARCEL REQUIREMENT #3 Protection of Adjacent Properties

- **Adjacent properties shall be protected from sediment deposition by appropriate use of vegetative buffer strips, sediment barriers or filters, dikes or mulching, or by a combination of these measures and other appropriate BMPs.**

SMALL PARCEL REQUIREMENT #4 Maintenance

- **All erosion and sediment control BMPs shall be regularly inspected and maintained to ensure continued performance of their intended function.**

SMALL PARCEL REQUIREMENT #5 Other BMPs

- **As required by the local Plan Approval Authority, other appropriate BMPs to mitigate the effects of increased runoff shall be applied.**

I-2.4 NEW DEVELOPMENT AND REDEVELOPMENT - APPLICATION OF MINIMUM REQUIREMENTS

I-2.4.1 New Development

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and/or land disturbing activity of one acre or greater, shall comply with Minimum Requirements #1 through #11 in Sections I-2.5 through I-2.15 and prepare a Stormwater Site Plan.

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and land disturbing activity of less than one acre, shall comply with Minimum Requirements #2 through #11 in Sections I-2.6 through I-2.15 and the Small Parcel Minimum Requirements found in section I-2.2, above. This category of development shall also prepare a Stormwater Site Plan that includes a Small Parcel Erosion and Sediment Control Plan.

This section does not apply to the construction of individual, detached, single family residences and duplexes. Those types of new development are included in the Small Parcel Minimum Requirements.

Objective: The objective of this standard is to define the application of the Minimum Requirements. The objective of these requirements is to reduce pollution and minimize erosion and sedimentation from new development.

Supplemental Guidelines: Basin planning is encouraged and may be used to tailor certain of the Minimum Requirements to a specific basin (see Minimum Requirement #9). The Minimum Requirements for Small Parcels are found in Section I-2.2. See page I-2-1 for the definition of new development. See Chapter I-3 for a description of Stormwater Site Plans.

I-2.4.2 Redevelopment

A. Where redevelopment of ≥ 5,000 square feet occurs:

The new development Minimum Requirements #1 through #11, Sections I-2.5 through I-2.15, shall apply to that portion of the site that is being redeveloped, and source control BMPs shall be applied to the entire site, including adjoining parcels if they are part of the project. A Stormwater Site Plan shall be prepared.

B. In addition to the above requirements, where one or more of the following conditions apply, a Stormwater Site Plan shall also be prepared that includes a schedule for implementing the Minimum Requirements to the maximum extent practicable, for the entire site, including adjoining parcels if they are part of the project. An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop redevelopment requirements that are tailored to a specific basin.

1. Existing sites greater than 1 acre in size with 50% or more impervious surface.

2. Sites that discharge to a receiving water that has a documented water quality problem. Subject to local priorities, a documented water quality problem includes, but is not limited to water bodies:

(i) Listed in reports required under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses;

(ii) Listed under section 304(l)(1)(A)(i),304(l)(1)(A)(ii), or 304(l)(1)(B) of the Clean Water Act as not expected to meet water quality standards or water quality goals;

(iii) Listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act that, without additional action to control nonpoint sources of pollution cannot reasonably be expected to attain or maintain water quality standards.

3. Sites where the need for additional stormwater control measures have been identified through a basin plan, the watershed ranking process under Ch. 400-12 WAC, or through Growth Management Act planning.

Objective: The objective of the redevelopment standard is to reduce pollution from existing sites. The long-term goal of this standard is to accomplish this reduction through development and implementation of basin plans.

Supplemental Guidelines: Minimum Requirements 1 through 11 always apply to the portion of the site that is being redeveloped, if the redevelopment is over 5,000 sq. ft. in size. In addition, source control BMPs are always required for the entire site. A basin plan could be used to vary the thresholds for application of the minimum requirements to the entire site, beyond the portion of the site that is being redeveloped. See Chapter I-3 for the description of a Stormwater Site Plan.

I-2.5 MINIMUM REQUIREMENT #1: EROSION AND SEDIMENT CONTROL

- **All new development and redevelopment that includes land disturbing activities of ≥1 acre shall comply with Erosion and Sediment Control Requirements 1 through 14, below. Compliance with the Erosion and Sediment Control Requirements shall be demonstrated through implementation of a Large Parcel Erosion and Sediment Control Plan.**

  All new development and redevelopment that includes land disturbing activities of <1 acre shall comply with the Small Parcel Minimum requirements found in section I-2.2, above. Compliance with the Small Parcel Requirements shall be demonstrated through implementation of a Small Parcel Erosion and Sediment Control Plan.

Objective: To control erosion and prevent sediment from leaving the site.

Supplemental Guidelines:

Large parcels are defined as those >1 acre in size. Parcels of this size are required to implement a Large Parcel ESC plan which meets the Erosion and Sediment Control Requirements found in Minimum Requirement #1. Additionally, a Permanent Stormwater Quality Control Plan (PSQC) must be developed which meets Minimum Requirements 2 through 11. An acceptable Stormwater Site Plan (SSP) for a large parcel contains both of these elements, the ESC plan, and the PSQC, and fulfills all the Minimum Requirements.

If an ESC plan is found to be inadequate (with respect to the Erosion and Sediment Control Requirements), then the Plan Approval Authority[1] within the Local Government will require that other BMPs be implemented, as appropriate.

Erosion and Sediment Control Minimum Requirements

Guidance to meet the requirements of the 1991 Puget Sound Water Quality Management Plan (as amended) is written in **bold**, and supplemental guidelines that serve as advice and other materials are not in bold.

The following erosion and sediment control requirements shall be met:

EROSION AND SEDIMENT CONTROL REQUIREMENT #1: Stabilization and Sediment Trapping

- **All exposed and unworked soils shall be stabilized by suitable application of BMPs. From October 1 to April 30, no soils shall remain unstabilized for more than 2 days. From May 1 to September 30, no soils shall remain unstabilized for more than 7 days. Prior to leaving the site, stormwater runoff shall pass through a sediment pond or sediment trap, or other appropriate BMPs.**

Supplemental Guidelines: This criterion applies both to soils not yet at final grade and soils at final grade. The type of stabilization BMP used may be different depending on the length of time that the soil is to remain unworked.

Soil stabilization refers to BMPs which protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include vegetative establishment, mulching, plastic covering, and the early application of gravel base on areas to be paved. Soil stabilization measures should be selected to be appropriate for the time of year, site conditions, and estimated duration of use. Soil stockpiles must be stabilized or protected with sediment trapping measures to prevent soil loss.

These requirements are *especially* important in areas adjacent to streams, wetlands or other sensitive or critical areas.

EROSION AND SEDIMENT CONTROL REQUIREMENT #2: Delineate Clearing and Easement Limits

- **In the field, mark clearing limits and/or any easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses.**

EROSION AND SEDIMENT CONTROL REQUIREMENT #3: Protection of Adjacent Properties

- **Properties adjacent to the project site shall be protected from sediment deposition.**

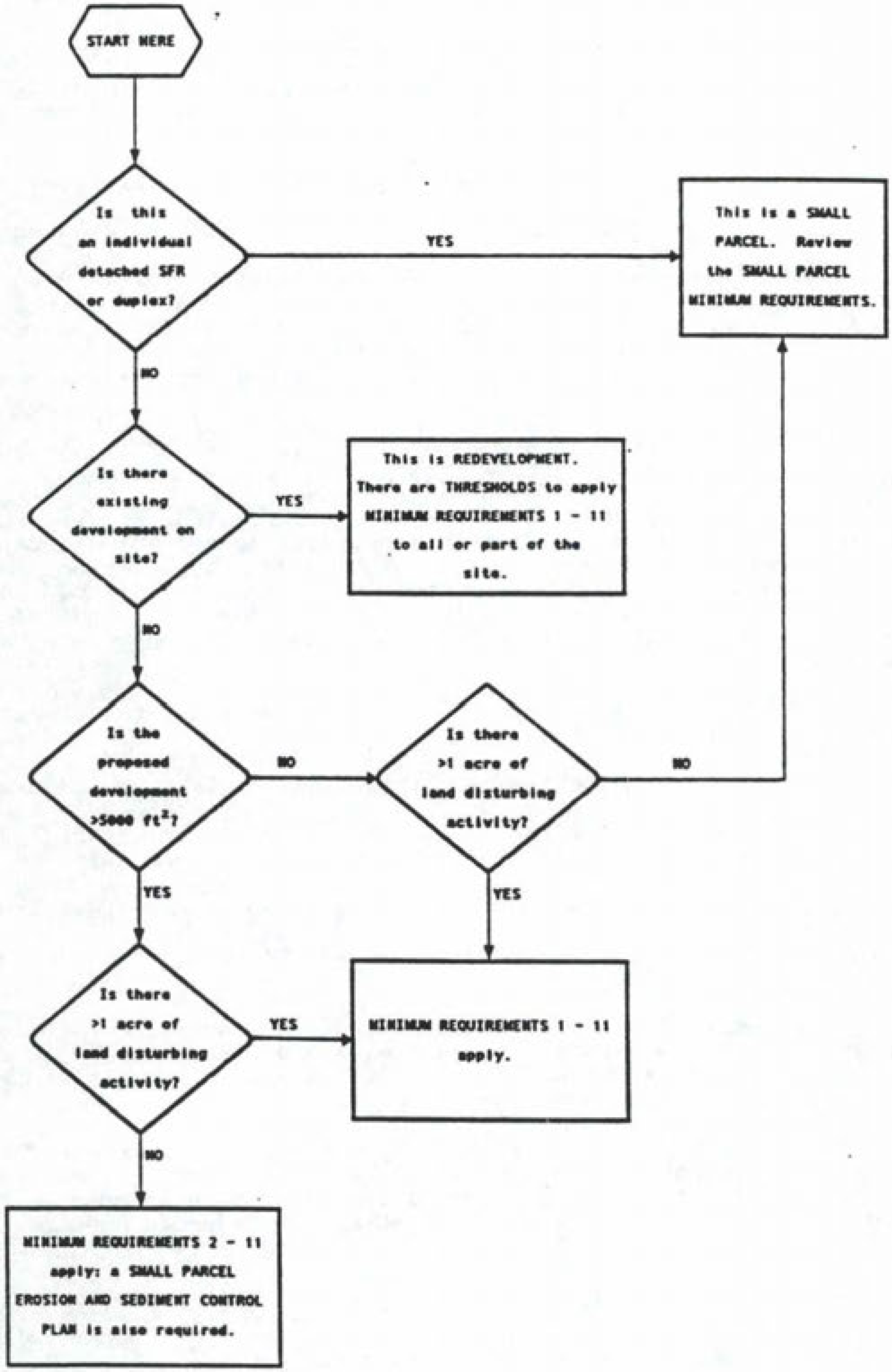
Supplemental Guidelines: This may be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, by installing perimeter controls such as sediment barriers, filters or dikes, or sediment basins, or by a combination of such measures.

Vegetated buffer strips may be used alone only where runoff in sheet flow is expected. Buffer strips should be at least 25 feet in width. If at any time it is found that a vegetated buffer strip alone is ineffective in stopping sediment movement onto adjacent property, additional perimeter controls must be provided.

---

1 The Plan Approval Authority is defined as that department within a local government that has been delegated authority to approve erosion and sediment control plans.

Figure I-2.1 Flowchart Demonstrating Minimum Requirements



EROSION AND SEDIMENT CONTROL REQUIREMENT #4: Timing and Stabilization of Sediment Trapping Measures

- **Sediment ponds and traps, perimeter dikes, sediment barriers, and other BMPs intended to trap sediment on-site shall be constructed as a first step in grading. These BMPs shall be functional before land disturbing activities take place. Earthen structures such as dams, dikes, and diversions shall be seeded and mulched according to the timing indicated in Erosion and Sediment Control Requirement #1.**

EROSION AND SEDIMENT CONTROL REQUIREMENT #5: Cut and Fill Slopes

- **Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. In addition, slopes shall be stabilized in accordance with Erosion and Sediment Control Requirement #1.**

Supplemental Guidelines: Consideration should be given to the length and steepness of the slope, the soil type, upslope drainage area, ground water conditions, and other applicable factors. Slopes which are found to be eroding excessively within two years of construction must be provided with additional slope stabilizing measures until the problem is corrected.

1. Roughened soil surfaces are preferred to smooth surfaces on slopes (see BMP E2.35 in Chapter II-5).

2. Interceptors (see BMP E2.55 in Chapter II-5) should be constructed at the top of long steep slopes which have significant drainage areas above the slope. Diversions or terraces may also be used to reduce slope length.

3. Concentrated stormwater should not be allowed to flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, or pipe slope drain (see BMP E2.25 in Chapter II-5).

4. Wherever a slope face crosses a water seepage plane which endangers the stability of the slope, adequate drainage or other protection should be provided (BMPs E2.30 and E2.75 in Chapter II-5).

EROSION AND SEDIMENT CONTROL REQUIREMENT #6: Controlling Off-site Erosion

- **Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.**

EROSION AND SEDIMENT CONTROL REQUIREMENT #7: Stabilization of Temporary Conveyance Channels and Outlets

- **All temporary on-site conveyance channels shall be designed, constructed and stabilized to prevent erosion from the expected velocity of flow from a 2-year, 24-hour frequency storm for the developed condition. Stabilization adequate to prevent erosion of outlets, adjacent streambanks, slopes and downstream reaches shall be provided at the outlets of all conveyance systems.**

EROSION AND SEDIMENT CONTROL REQUIREMENT #8: Storm Drain Inlet Protection

- **All storm drain inlets made operable during construction shall be protected so that stormwater runoff shall not enter the conveyance system without first being filtered or otherwise treated to remove sediment.**

EROSION AND SEDIMENT CONTROL REQUIREMENT #9: Underground Utility Construction

- The construction of underground utility lines shall be subject to the following criteria:

  (i) Where feasible, no more than 500 feet of trench shall be opened at one time.

  (ii) Where consistent with safety and space considerations, excavated material shall be placed on the uphill side of trenches.

  (iii) Trench dewatering devices shall discharge into a sediment trap or sediment pond.

EROSION AND SEDIMENT CONTROL REQUIREMENT #10: Construction Access Routes

- Wherever construction vehicle access routes intersect paved roads, provisions must be made to minimize the transport of sediment (mud) onto the paved road. If sediment is transported onto a road surface, the roads shall be cleaned thoroughly at the end of each day. Sediment shall be removed from roads by shoveling or sweeping and be transported to a controlled sediment disposal area. Street washing shall be allowed only after sediment is removed in this manner.

EROSION AND SEDIMENT CONTROL REQUIREMENT #11: Removal of Temporary BMPs

- All temporary erosion and sediment control BMPs shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

EROSION AND SEDIMENT CONTROL REQUIREMENT #12: Dewatering Construction Sites

- Dewatering devices shall discharge into a sediment trap or sediment pond.

EROSION AND SEDIMENT CONTROL REQUIREMENT #13: Control of Pollutants Other Than Sediment on Construction Sites

- All pollutants other than sediment that occur on-site during construction shall be handled and disposed of in a manner that does not cause contamination of stormwater.

EROSION AND SEDIMENT CONTROL REQUIREMENT #14: Maintenance

- All temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

EROSION AND SEDIMENT CONTROL REQUIREMENT #15: Financial Liability

- Performance bonding, or other appropriate financial instruments, shall be required for all projects to ensure compliance with the approved erosion and sediment control plan.

I-2.6 MINIMUM REQUIREMENT #2: PRESERVATION OF NATURAL DRAINAGE SYSTEMS

- Natural drainage patterns shall be maintained, and discharges from the site shall occur at the natural location, to the maximum extent practicable.

Objective: To preserve and utilize natural drainage systems to the fullest extent because of the multiple stormwater benefits these systems provide.

Supplemental Guidelines: Natural drainage systems provide many water quality benefits and should be preserved to the fullest extent possible. In addition to conveying and attenuating stormwater runoff, these systems are less erosive, provide ground water recharge, and support important plant and wildlife resources. Effective utilization of the natural system can maintain environmental and aesthetic attributes of a site as well as be a cost-effective measure to convey stormwater runoff.

Creating new drainage patterns requires more site disturbance and can upset stream dynamics of the drainage system, thus tending to increase erosion and sedimentation. Creating new discharge points can create significant streambank erosion problems as the receiving water body typically must adjust to the new flows. Newly created drainage patterns can seldom, if ever, provide the multiple benefits of natural drainage systems. Where no conveyance system exists at the adjacent downstream property line and the discharge was previously unconcentrated flow or significantly lower concentrated flow, then measures must be taken to prevent downstream impacts. Necessary drainage easements may be obtained from downstream property owners.

I-2.7 MINIMUM REQUIREMENT #3: SOURCE CONTROL OF POLLUTION

- **Source control BMPs shall be applied to all projects to the maximum extent practicable. Source control BMPs shall be selected, designed, and maintained according to an approved manual.**

  An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop source control requirements that are tailored to a specific basin, however, in all circumstances, source control BMPs shall be required for all sites.

Objective: The intention of source control BMPs is to prevent stormwater from coming in contact with pollutants. They are a cost effective means of reducing pollutants in stormwater, and, therefore, should be a first consideration in all projects.

Supplemental Guidelines: A list of many source control BMPs is provided in the BMP selection chapter, Chapter I-4. For construction sites see Chapter II-5; for post-construction development sites see Volume III; for specific urban land uses see Volume IV.

I-2.8 MINIMUM REQUIREMENT #4: RUNOFF TREATMENT BMPS

- **All projects shall provide treatment of stormwater. Treatment BMPs shall be sized to capture and treat the water quality design storm, defined as the 6-month, 24-hour return period storm. The first priority for treatment shall be to infiltrate as much as possible of the water quality design storm, only if site conditions are appropriate and ground water quality will not be impaired. Direct discharge of untreated stormwater to ground water is prohibited. All treatment BMPs shall be selected, designed, and maintained according to an approved manual.**

  Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop runoff treatment requirements that are tailored to a specific basin.

Objective: The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms. When site conditions are appropriate infiltration can potentially be the most effective BMP for runoff treatment.

Supplemental Guidelines: See Volume III. The water quality design storm (see Appendix AI-2.1) is intended to capture more than 90 percent of the annual runoff.

Infiltration can provide both treatment of stormwater, through the ability of certain soils to remove pollutants, and volume control of stormwater, by decreasing the amount of water that runs off to surface water. Infiltration can be very effective at treating stormwater runoff but soil conditions must be appropriate to achieve effective treatment while not impacting ground water resources. Methods currently in use such as direct discharge into dry wells do not achieve adequate water quality treatment and are therefore not permitted.

If stormwater is being discharged to a stream, see I-2.9, Streambank Erosion Control for additional requirements.

If stormwater is being discharged to a wetland, see I-2.10, Wetlands for additional requirements.

I-2.9 MINIMUM REQUIREMENT #5: STREAMBANK EROSION CONTROL

- **The requirement below applies only to situations where stormwater runoff is discharged directly or indirectly to a stream, and must be met in addition to meeting the requirements in Minimum Requirement #4, Runoff Treatment BMPs:**

  Stormwater discharges to streams shall control streambank erosion by limiting the peak rate of runoff from individual development sites to 50 percent of the existing condition 2-year, 24-hour design storm while maintaining the existing condition peak runoff rate for the 10-year, 24-hour and 100-year, 24-hour design storms. As the first priority, streambank erosion control BMPs shall utilize infiltration to the fullest extent practicable, only if site conditions are appropriate and ground water quality is protected. Streambank erosion control BMPs shall be selected, designed, and maintained according to an approved manual.

  Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

  An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop streambank erosion control requirements that are tailored to a specific basin.

Objective: To reduce streambank erosion which results from increased runoff due to development. The standard is intended to reduce the frequency and magnitude of bankfull flow conditions, which are highly erosive and increase dramatically as a result of development. Conventional flood detention practices do not adequately control streambank erosion because only the peak rate of flow is decreased, not the *frequency* and *duration* of bankfull conditions.

Supplemental Guidelines: See Chapter III-4. Reduction of flows through infiltration decreases streambank erosion and helps to maintain base flow throughout the summer months. However, infiltration should only be used where ground water quality is not threatened by such discharges. The use of an artificial treatment system, such as an aquatard (see Chapter III-3) shall be considered in areas with highly permeable soils. Treatment of the water quality design storm must be accomplished prior to discharge to these soils. If highly permeable soils are present they should be utilized for streambank erosion control by infiltrating flows greater than the water quality design storm.

I-2.10 MINIMUM REQUIREMENT #6: WETLANDS

- **The requirements below apply only to situations where stormwater discharges directly or indirectly through a conveyance system into a wetland, and must be met <u>in addition</u> to meeting the requirements in Minimum Standard #4, Runoff Treatment BMPs.**

  (a) Stormwater discharges to wetlands must be controlled and treated to the extent necessary to meet the State Water Quality Standards, Ch. 173-201 WAC, or Ground Water Quality Standards, Ch. 173-200 WAC, as appropriate.

  (b) Discharges to wetlands shall maintain the hydroperiod and flows of existing site conditions to the extent necessary to protect the characteristic uses of the wetland. Prior to discharging to a wetland, alternative discharge locations shall be evaluated, and natural water storage and infiltration opportunities outside the wetland shall be maximized.

  (c) Created wetlands that are intended to mitigate for loss of wetland acreage, function and value shall not be designed to also treat stormwater.

  (d) In order for constructed wetlands to be considered treatment systems, they must be constructed on sites that are not wetlands and they must be managed for stormwater treatment. If these systems are not managed and maintained in accordance with an approved manual for a period exceeding three years these systems may no longer be considered constructed wetlands. Discharges from constructed wetlands to waters of the state (including discharges to natural wetlands) are regulated under Ch. 90.48 RCW, Ch. 173-201 WAC, and Ch. 173-200 WAC.

  (e) Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

  An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop requirements for wetlands that are tailored to a specific basin.

<u>Objective</u>: To ensure that wetlands receive the same level of protection as any other waters of the state. Wetlands are extremely important natural resources which provide multiple stormwater benefits, including ground water recharge, flood control, and streambank erosion protection. They are easily impacted by development unless careful planning and management are conducted. Wetlands can be severely degraded by stormwater discharges from urban development due to pollutants in the runoff and also due to disruption of natural hydrologic functioning of the wetland system. Changes in water levels and the duration of inundations are of particular concern.

Supplemental Guidelines: See Chapter III-5. These requirements are a management tool to assist in meeting the state water quality standards. While it is always necessary to pre-treat stormwater prior to discharge to a wetland, there are limited circumstances where wetlands may be used for detention of stormwater.

Definitions: See glossary for definitions of wetlands, constructed wetland, created wetland, and abandonment.

I-2.11 MINIMUM REQUIREMENT #7: WATER QUALITY SENSITIVE AREAS

- **Where local governments determine that the Minimum Requirements do not provide adequate protection of water quality sensitive areas, either on-site or within the basin, more stringent controls shall be required to protect water quality.**

  Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

  An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop requirements for water quality sensitive areas that are tailored to a specific basin.

Objective: To ensure protection of water quality in sensitive areas.

Supplemental Guidelines: Water quality sensitive areas are areas that are sensitive to a change in water quality, including but not limited to, lakes, ground water management areas, ground water special protection areas, sole source aquifers, critical aquifer recharge areas, well head protection areas, closed depressions, fish spawning and rearing habitat, wildlife habitat, and shellfish protection areas. Areas such as steep or unstable slopes or erosive stream banks which can cause water quality problems should also be included. Water quality sensitive areas may be identified through jurisdiction-wide inventories, the watershed planning process required under Ch. 400-12 WAC, critical area designation in accordance with Ch. 365-190 WAC, local drainage basin planning, and/or on a site-by-site basis (e.g. using a threshold determination under SEPA).

I-2.12 MINIMUM REQUIREMENT #8: OFF-SITE ANALYSIS AND MITIGATION

- **All development projects shall conduct an analysis of off-site water quality impacts resulting from the project and shall mitigate these impacts. The analysis shall extend a minimum of one-fourth of a mile downstream from the project. The existing or potential impacts to be evaluated and mitigated shall include, at a minimum, but not be limited to:**

  (i) excessive sedimentation
  (ii) streambank erosion
  (iii) discharges to ground water contributing or recharge zones
  (iv) violations of water quality standards
  (v) spills and discharges of priority pollutants

Objective: To ensure that future impacts from the project will be controlled and/or existing impacts will not be aggravated by the project.

Supplemental Guidelines: Further information on off-site analysis is being developed.

I-2.13 MINIMUM REQUIREMENT #9: BASIN PLANNING

- **Adopted and implemented watershed-based basin plans may be used to modify any or all of the Minimum Requirements, provided that the level of protection for surface or ground water achieved by the basin plan will equal or exceed that which would be achieved by the Minimum Requirements in the absence of a basin**

plan. Basin plans shall evaluate and include, as necessary, retrofitting of BMPs for existing development and/or redevelopment in order to achieve watershed-wide pollutant reduction goals. Standards developed from basin plans shall not modify any of the above requirements until the basin plan is formally adopted and fully implemented by local government. Basin plans shall be developed according to an approved manual.

Objective: To promote watershed-based planning as a means to develop and implement comprehensive water quality protection measures. Primary objectives of basin planning are to reduce pollutant loads and hydrologic impacts to streams and wetlands.

Supplemental Guidelines: While Minimum Requirements #3 through #7 establish protection standards for individual sites, they do not evaluate the overall pollution impacts and protection opportunities which could exist at the watershed level. In order for a basin plan to serve as a means of modifying the minimum requirements it must be formally adopted by all jurisdictions that have responsibilities under the basin plan, and construction and regulations called for by the plan must be complete. This is what is meant by an adopted and implemented basin plan.

Basin planning provides a mechanism by which the on-site standards can be evaluated and refined based on an analysis of an entire watershed. Basin plans are especially well-suited to develop control strategies to address impacts from future development and to correct specific problems whose sources are known or suspected. Basin plans can be effective at addressing both long-term cumulative impacts of pollutant loads and short-term acute impacts of pollutant concentrations, as well as hydrologic impacts to streams and wetlands.

In general, the standards established by basin plans will be site-specific but may be augmented with regional solutions for Source Control (Minimum Requirement #2) and Streambank Erosion Control (Minimum Requirement #4).

I-2.14 MINIMUM REQUIREMENT #10: OPERATION AND MAINTENANCE

- **An operation and maintenance schedule shall be provided for all proposed stormwater facilities and BMPs, and the party (or parties) responsible for maintenance and operation shall be identified.**

Objective: To ensure that stormwater control facilities are adequately maintained and operated properly.

Supplemental Guidelines: Inadequate maintenance is likely the leading cause of failure for stormwater control facilities. The description of each BMP in Volume II and III includes a section on maintenance. The Guidance Manual also includes a section on developing an operation and maintenance program and a model operation and maintenance ordinance.

I-2.15 MINIMUM REQUIREMENT #11: FINANCIAL LIABILITY

- **Performance bonding or other appropriate financial instruments shall be required for all projects to ensure compliance with these standards.**

Objective: To ensure that development projects have adequate financial resources to fully implement stormwater management plan requirements and that liability is not unduly incurred upon local governments.

Supplemental Guidelines: The type of financial instrument required is less important than ensuring that there are adequate funds available in the event that non-compliance occurs.

I-2.16 EXCEPTIONS

- **Exceptions to Minimum Requirements #1 through #10 may be granted prior to permit approval and construction. An exception may be granted following a public hearing, provided that a written finding of fact is prepared, that addresses the following:**

  (i) The exception provides equivalent environmental protection and is in the overriding public interest; and that the objectives of safety, function, environmental protection and facility maintenance, based upon sound engineering, are fully met;

  (ii) That there are special physical circumstances or conditions affecting the property such that the strict application of these provisions would deprive the applicant of all reasonable use of the parcel of land in question, and every effort to find creative ways to meet the intent of the Minimum Requirements has been made;

  (iii) That the granting of the exception will not be detrimental to the public health and welfare, nor injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and

  (iv) The exception is the least possible exception that could be granted to comply with the intent of the Minimum Requirements.

Supplemental Guidelines: Ecology encourages the Plan Approval Authority to impose additional or more stringent criteria as appropriate for their area. Additionally, criteria which may be inappropriate or too restrictive for an area may be modified through basin planning (Minimum Requirement #9). Modification of any of the minimum requirements which are deemed inappropriate for the site may be done by granting an exception.

The exception procedure is an important element of the plan review and enforcement programs. It is intended to maintain a necessary flexible working relationship between local officials and applicants. Plan Approval Authorities should consider these requests judiciously, keeping in mind both the need of the applicant to maximize cost-effectiveness and the need to protect off-site properties and resources from damage.

I-2.17 EXPERIMENTAL BMPs

Experimental best management practices are defined as BMPs which have not been tested and evaluated by the Department of Ecology in collaboration with local governments and technical experts. Some so-called Experimental BMPs will likely be minor variations on an existing theme. In that case, Ecology would review and approve or disapprove the BMP in as timely a manner as possible. Where new designs are developed (examples as below, in Section I-2.17.2), the review will be extended through the use of a standing committee of technical experts. These persons will review and comment on the practice, and Ecology will then determine whether or not these BMPs should be approved and/or added to this manual.

I-2.17.1 Approval of Experimental BMPs

Approval to use an Experimental BMP may be granted subject to initial approval by the Department of Ecology and the local government. If such Experimental BMPs prove useful they may be incorporated into later editions of this manual following appraisal of the results and appropriate technical review conducted by Ecology in collaboration with local governments and other interested parties. Approval to use an Experimental BMP will only be granted when a suitable contingency plan using approved BMPs has been provided by the applicant to be used in the event that the Experimental BMP does not perform adequately.

In addition, several Experimental BMPs have been included in the manual. People may wish to use these BMPs on a trial basis, subject to approval by the local government and provision of a contingency plan. In any event, use of Experimental BMPs is encouraged whenever applied research is being undertaken so that more information is made available to facilitate judgement on their applicability and possible adoption as an approved.

I-2.17.2 Example Experimental BMPs

The two BMPs described below are examples of Experimental BMPs where a thorough design review and monitoring process is occurring. Both designs have undergone significant modification based on the monitoring data collected and both are still in the prototype stage. Please note that these examples are presented for informational purposes only. While these Experimental BMPs appear to be effective at controlling some types of pollutants, Ecology is not in a position to confirm or deny their efficacy at this time.

The two Experimental BMPs that are currently under development are a catchbasin filter system designed by Emcon Northwest, and a compost stormwater treatment system designed by W&H Pacific.

Catchbasin Filter System

EMCON Northwest, Inc. has recently developed a catchbasin filter (patent pending) that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material (see Figure II-5.26). This type of system may not be applicable in all catchbasins but would work well at construction sites, industrial facilities, service stations, marinas/boatyards, etc.

During research and development of the catchbasin filter, EMCON Northwest, Inc. has found that particulates as small as 15 microns are retained by the filter. Additionally, high levels of particulate heavy metals, oil and grease and TSS have been removed at both industrial facilities and construction sites. This system would be useful in small drainage areas, and for treatment of highly turbid runoff prior to discharge.

For further information, contact John MacPherson at EMCON Northwest Inc., (206) 485-5000.

Compost Stormwater Treatment System

W&H Pacific worked with the Washington County Dept. of Land Use and Transportation (WCDLUT), Oregon, to develop this experimental BMP. The United Sewage Agency (USA) provided sampling and laboratory analysis for the project; the Portland Metropolitan Service District (Metro) provided additional funding; and the University of Washington College of Forest Resources was contracted to perform bench-scale leaching and adsorption capacity tests on selected composts. The compost chosen for the prototype facility was made from deciduous leaves collected in the fall; other types of compost evaluated were not satisfactory.

This project is a good example of intergovernmental cooperation and interaction between public and private sectors in developing new and potentially cost-effective technology for stormwater pollution control. The goal of the project was to effectively treat road runoff using a BMP which reduced the amount of land necessary.

The prototype test facility is located at S.W. 185th Avenue in Washington County, Oregon, and serves a total drainage area of 72 acres. The facility is designed for a peak hydraulic loading of 6.7 cfs (one-third the 2-year design storm). Higher flows are bypassed. Nine storms were monitored in 1991, and the system has been successful in removing, to low levels, many types of conventional pollutants .

The prototype facility utilized 3% of the land area required for a properly designed stormwater detention pond sized for the same site conditions.

The project recently won an Engineering Excellence Grand Award from the Consulting Engineers Council of Oregon, as well as a national Grand Award from the American Consulting Engineers Council.

For further information on this experimental BMP, contact Bill Stewart at W&H Pacific, (503) 626-0455.

APPENDIX AI-2.1

DERIVATION OF THE WATER QUALITY DESIGN STORM

In instances where the stormwater management requirement is treatment to remove pollutants only without an additional requirement to control peak rate discharge there arises the need to establish an appropriate design storm for sizing of treatment BMPs. This design storm needs to be the minimum size to provide treatment of all the runoff volume from the site except that from relatively rare floods. Sizing a treatment facility for infrequent storms would result in a large facility that would be greatly under-utilized most of the time. The cost becomes prohibitive to treat a few extra percent of the total runoff volume.

TABLE AI-2.1 ANALYSIS OF SEA-TAC RAINFALL FROM 1950 - 1977 (Prepared by Resource Planning Associates (1))

Storm Event Size	Precip. Amount	# of Events	Rainfall Amount of Larger Events	Proportion of Total[2]
1-month, 24-hr.	0.65"	390	415"	62%
6-month, 24-hr.	1.35"	58	101"	91%
1-year, 24-hr.	1.60"	31	55"	95%
2-year, 24-hr.	2.00"	9	23"	98%

[2] The total rainfall from 1950 to 1977 was 1,100". The proportion of total represents the amount of rainfall accounted for by that storm size, and smaller sizes. For example the 1-month, 24-hour storm, and smaller storms, accounted for 1,100 - 415/1,100 = 62%.

Table AI-2.1 shows that relatively small storms account for a considerable proportion of the total rainfall; for example the 6-month, 24-hour, and smaller storms, accounted for over 90% of the total rainfall during the period 1950 through 1977; 98% of the rainfall was accounted for by storm sizes up to the 2-year, 24-hour storm. Of course the proportion of runoff produced by the rainfall for any particular surface type will increase with increasing storm size. On the other hand, smaller storms may tend to produce runoff with higher concentrations of some pollutants because of the "first flush" effect which may occur in highly impervious areas following a dry spell. Therefore, as a first approximation, it seems reasonable to simply assume that the proportion of rainfall is approximately equal to the proportion of runoff.

Having arrived at this point, the next step is to decide what is an appropriate runoff proportion to use in sizing the water quality storm. Ideally we would want to treat 100% of all runoff but the data in Table AI-2.1 show that the incremental proportion of rainfall (and hence runoff) accounted for rapidly diminishes for storm sizes larger than the 6-month, 24-hour storm. This means that the marginal costs for treating stormwater will rapidly increase when facilities are sized for storms larger than the 6-month, 24-hour storm. This point is demonstrated by considering a simple example using a one acre urban site with a curve number of 95 and time of concentration of 10 minutes. Using the SBUH method the following peak runoff rates and runoff volumes were obtained:

Storm Event	Precip.	Peak Runoff	Volume
1-mo., 24-hr.	0.65"	0.061 cfs	1000 cu-ft
6-mo., 24-hr.	1.3"	0.21 cfs	3000 cu-ft
1-yr., 24-hr.	1.6"	0.28 cfs	4010 cu-ft
2-yr., 24-hr.	2.0"	0.38 cfs	5380 cu-ft

Since the treatment facility size will be in proportion to the peak runoff or runoff volume we can next compare the facility size required for each design storm with the proportion of total runoff generated by that and smaller storms (estimated from Table AI-2.1). (For this example we can use the total runoff volume as the indicator of required facility size.)

Storm Event	Facility Size	Proportion of Runoff
1-mo., 24-hr.	1000 cu-ft	62%
6-mo., 24-hr.	3000 cu-ft	91%
1-yr., 24-hr.	4010 cu-ft	95%
2-yr., 24-hr.	5380 cu-ft	98%

From this we can calculate that greatly diminishing returns are achieved by increasing the facility size beyond that needed for the 6-month, 24-hour storm. Sizing the facility for a 1-year, 24-hour storm instead of a 6-month storm requires an increase of about 33% for an increase of only 4% of volume treated from an already high value of approximately 90%. Further increasing the size to that required for the 2-year, 24-hour storm requires a further increment of about 36% for a further gain of only 3% in the long term runoff volume treated.

Therefore, as a first approximation, it seems reasonable to select the 6-month, 24-hour design storm as the Water Quality design storm.

(However, protection of beneficial uses in receiving waters will always be required. Therefore there may be instances, depending on the nature of the pollutants to be controlled and the receiving waters, that the 6-month storm will be deemed inadequate by the local government and/or Ecology or other State agencies. In these instances a larger design storm shall be chosen.)

Having selected the 6-month, 24-hour design storm as the first approximation, the next step is to determine a method for estimating the size of the storm, given that the isopluvial maps do not provide values for less than the 2-year storm. One method is to plot the logarithm of the return period against the precipitation value for the published storms - the 2, 5, 10, 25, 50 and 100-year frequencies. This was done for several locations around the Puget Sound basin - Bellingham, Everett, Seattle, Tacoma and Olympia. In each case a near perfect regression line was obtained, except that the slope and intercept varied in accordance with the differences in rainfall received at the various locations. Each regression line was then extrapolated to the 6-month frequency and rainfall value estimated. The ratio of the 6-month value to the 2-year value was then determined for each station. This ratio was found to average 0.64 with little variation between the stations. **Therefore, for a rule of thumb method, the 6-month, 24-hour design storm can be estimated for any location within the Puget Sound basin as 0.64 times the 2-year, 24-hour storm value.**

References:

(1) Resource Planning Associates, Water Quality Best Management Practices Manual for the City of Seattle, 1989.

APPENDIX AI-2.2

ADDITIONAL BASIN PLANNING GUIDANCE AS APPLIED TO THE MINIMUM REQUIREMENTS

Basin Planning Applied to Source Control (Minimum Requirement #3)

Basin plans should identify potential sources of pollution and develop strategies to eliminate or control these sources to the fullest extent possible. At a minimum, a basin plan should include the following source control strategies:

(1) Detection and correction of illicit discharges to storm sewer systems, including the use of dry weather sampling and dye-tracing techniques;
(2) Identification of existing businesses, industries, utilities, and other activities which may store materials susceptible to spillage or leakage of pollutants into the storm sewer system;
(3) Elimination or control of pollutant sources identified in (2);
(4) Identification and control of future businesses, industries, utilities, and other activities which may store materials susceptible to spillage or leakage of pollutants into the storm sewer system;
(5) Training and Public education

Basin Planning Applied to Runoff Treatment (Minimum Requirement #4)

Basin plans should develop runoff treatment standards to reduce pollutant loads based on an evaluation of the water resources to be protected within or downstream of a watershed. The evaluation must include an analysis of existing and future conditions. Additional levels of control beyond Minimum Requirement #4 may be justified in order to control the impacts of future development. While direct cause-and-effect impacts will rarely be known for future development, standards should be developed based on an evaluation of pollutant loads and modeling of receiving water conditions.

Runoff treatment standards developed from a basin plan must apply to individual development sites. Regional treatment BMPs, in general, will not be considered an acceptable substitute for on-site treatment standards for two primary reasons. One is the stream systems upstream of regional facilities are defined as waters of the state and shall be protected (i.e., they are not to be considered as simply conveyance systems to the regional facility). Second, the pollutant removal effectiveness of regional treatment BMPs has not been demonstrated to be equivalent to on-site treatment BMPs. Regional BMPs may offer some advantages in construction and operation and maintenance costs and Ecology may approve such BMPs on a case-by-case basis.

On-site standards developed from basin planning can be flexible provided that the level of runoff treatment for all sites in a watershed is equivalent to that which would be achieved by Minimum Requirement #3. For example, site A may be able to achieve a higher pollutant load reduction goal than site B and this is acceptable provided that the two sites together achieve the equivalent level of treatment provided by the Minimum Requirement #3.

Basin plans shall evaluate retrofitting opportunities, such as installation of extended detention outlets for existing stormwater detention facilities.

Basin Planning Applied to Streambank Erosion Control (Minimum Requirement #5)

Basin planning is well-suited to control streambank erosion for both existing and future conditions. Streambank erosion control standards developed from a basin plan may include a combination of on-site, regional, and stream protection/rehabilitation measures. On-site standards shall be the primary mechanism to protect streambanks from the impacts of future conditions. Regional streambank erosion control BMPs are to used primarily to correct existing downstream streambank erosion problems. Stream protection/rehabilitation measures may be applied wherever streambank erosion problems currently exist which will not be corrected by on-site or regional BMPs.

Basin Planning Applied to Wetlands and Water Quality Sensitive Areas (Minimum - Requirements #6 and #7, respectively)

Basin planning should be used to develop additional protection standards for wetlands and water quality sensitive areas. These standards must include source control, runoff treatment, and streambank erosion control standards. Additional standards may also be developed which are specific to the needs of the wetland or sensitive area to be protected, such as management of a wetland's hydrology and hydroperiods, establishment of buffer zones for wellheads, and ground water contributing and recharge zones, and management of streamflows for the benefit of fish populations.

CHAPTER III-4

DETENTION FACILITIES

III-4.1 INTRODUCTION

III-4.1.1 Background

Detention facilities, by design, provide storage of runoff resulting from development. Properly designed detention facilities can provide effective treatment of pollutants contained in stormwater, especially particulates which can settle out during quiescent conditions. In addition, detention BMPs can reduce streambank erosion and flooding by temporarily detaining runoff before releasing it at flowrates and frequencies similar to those occurring under natural hydrologic conditions. Detention facilities include ponds, vaults, and tanks.

III-4.1.2 Purpose and Scope

The purpose of this chapter is to present general and specific criteria for the evaluation, design, construction, and maintenance of detention facilities. In particular, this chapter provides guidance on how BMPs can be designed to accomplish two primary stormwater management objectives, *runoff treatment* and *streambank erosion control* (recall that *source control* is another objective which is required in all cases).

Sections III-4.2 and III-4.3 should be read first as they discuss important concepts and design criteria applicable to detention BMPs. Sections III-4.4 and III-4.5 provide detailed standards and specifications for the following detention BMPs:

BMP RD.05	Wet Pond (Conventional Pollutants)
BMP RD.06	Wet Pond (Nutrient Control)
BMP RD.09	Constructed Wetland
BMP RD.10	Presettling Basin
BMP RD.11	Extended Detention Dry Pond
BMP RD.15	Wet Vault/Tank
BMP RD.20	Extended Detention Dry Vault/Tank

III-4.2 RUNOFF TREATMENT AND STREAMBANK EROSION CONTROL

III-4.2.1 Background

Minimum Requirements #4 and #5 require development sites to provide runoff treatment and control streambank erosion, respectively (see Chapter I-2). The runoff treatment design storm is the 6-month, 24-hour event. The streambank erosion control standard is to limit peak flows discharged from the *developed* site to 50 percent of the *existing* condition 2-year, 24-hour event and maintain the *existing* condition peak flow rates for the 10-year and 100-year, 24-hour design storms, with appropriate correction factors (see Chapter III-1 for further details).

Runoff Treatment

Runoff treatment is accomplished by detention BMPs using a variety of pollutant removal mechanisms, including sedimentation, biological uptake, and vegetative filtration. Runoff treatment is to be provided for up to the 6-month, 24-hour design storm. The rationale for selecting this storm is that over 90 percent of the annual runoff events will be captured and treated by BMPs sized for this event. The 6-month, 24-hour storm is determined by multiplying the 2-year, 24-hour event by a factor of 0.64. The size of the 6-month storm averages about 2 inches in the Puget

Sound Basin but will vary from about 0.65 inches to over 3 inches, depending on where a site is located (see the isopluvial maps in the appendix of Chapter III-1).

Streambank Erosion Control

Streambank erosion control is accomplished in detention BMPs by detaining runoff and then releasing it back to stream systems at reduced flowrates. The goal is to replicate, to the extent possible, the pre-development hydrologic regime. Streambank erosion control is required whenever discharges are made, directly or indirectly, to a stream system.

A typical detention BMP configuration maintains a permanent pool of water as a "dead storage" area for treatment purposes and a "live storage" area above the permanent pool in order to temporarily detain runoff for streambank erosion control purposes. Figure III-4.1 illustrates this configuration.

Limiting streambank erosion and the destruction of fish habitat can be achieved by limiting the rate of release of runoff from the 2-year design storm to 50 percent of the existing condition rate. This criterion is based on advice from the Washington Department of Fisheries (see Appendix AIII-4.1). For further technical details, please contact the Habitat Management Division of that Department. The rationale for this release rate is prevention of both the frequency and duration of flows at the highly erosive bankfull stage. This would occur if the runoff was released at 100 percent of the existing condition rate because of the increased volume of runoff associated with development. If all of the 2-year, 24-hour storm can be infiltrated the restrictive release rate is no longer necessary.

Note that a coincident benefit of this detention requirement is extended detention in many instances. Releasing the runoff from the 2-year storm at 50 percent of the existing condition rate may result in this runoff being detained for approximately 40 hours, or longer. Longer detention periods will be achieved on sites that have higher ratios of pre-developed to post-developed peak flows, lower SCS curve numbers, and longer times of concentration.

The rationale for controlling the large, infrequent storms (i.e., the 10-year and 100-year events) is to provide additional streambank erosion protection as well as flood protection.

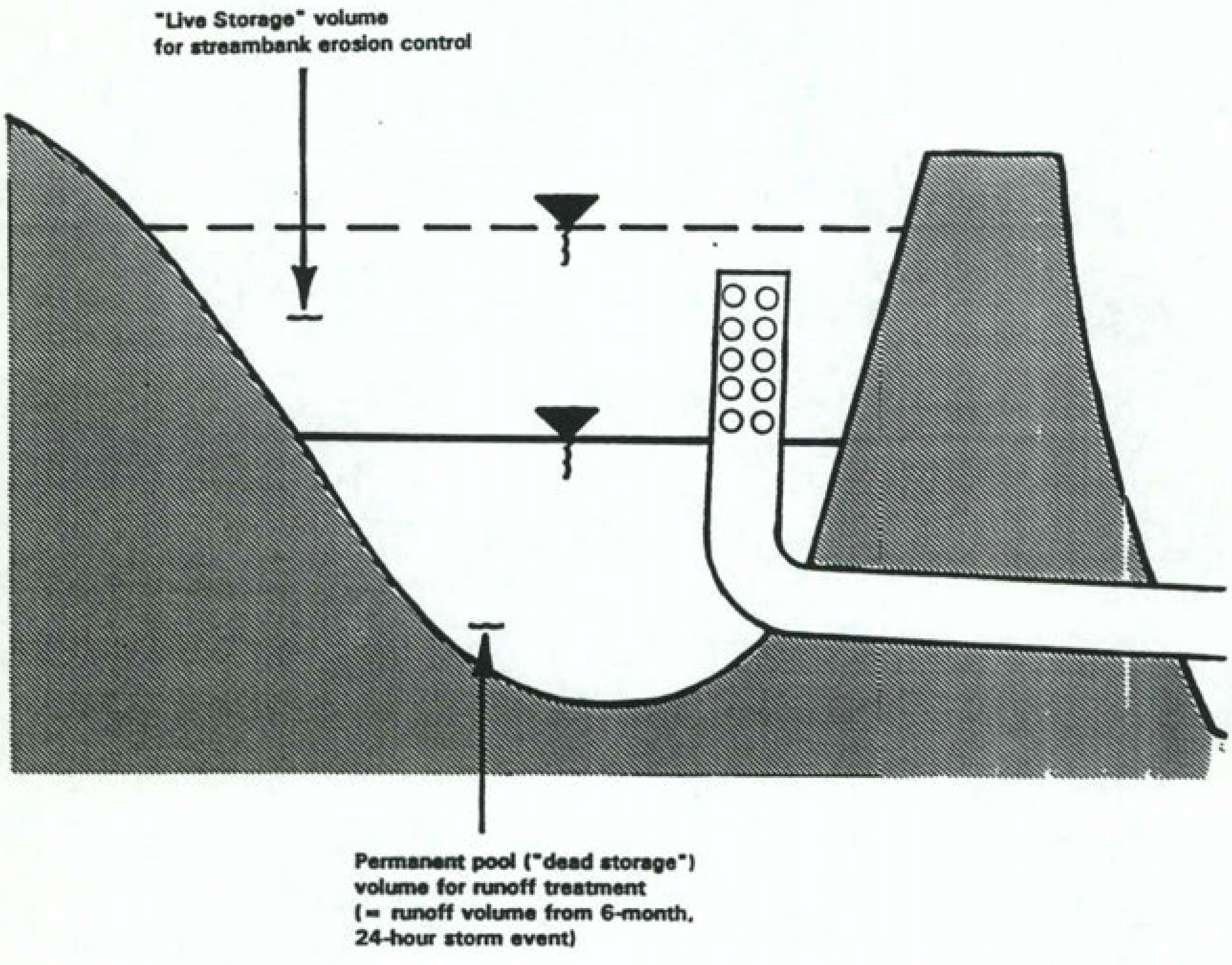
Note: A correction factor must be applied to the detention volume for streambank erosion control in order to account for weaknesses in current hydrologic analysis methods. When using SCS hydrologic analysis methods to estimate runoff for 24-hour duration storms, the correction factor should vary from 20% for residential areas up to 50% for commercial areas. Until the work on the 7-day design storm, or other alternative methods for estimating runoff is complete the design engineer is advised to apply a correction factor. The correction factor is to be applied to the volume of the BMP without changing the BMP depth or design of the outlet device. See Chapter III-1 for a further discussion of this issue.

(Note: An adopted and approved basin plan (Minimum Requirement #9 in Chapter I-2) may be used to develop streambank erosion control requirements that are tailored to a specific basin).

Additional Requirements

Additional requirements may apply if a development discharges into a natural or created (mitigated) wetland, lake, and other sensitive waterbodies (see Minimum Requirements #4 - #7 in Chapter I-2).

Figure III-4.1
Typical Wet Pond-type Detention BMP



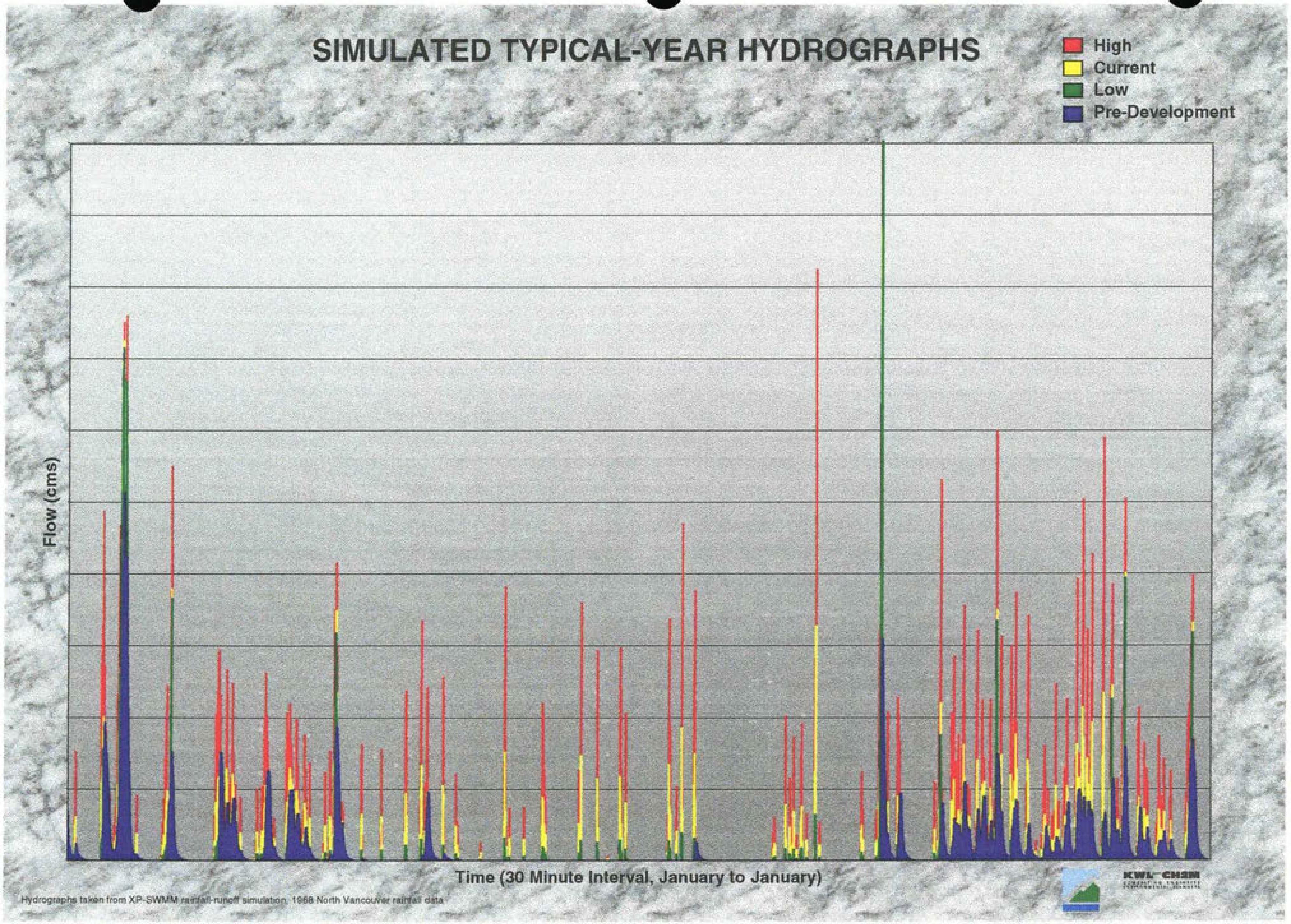

SIMULATED TYPICAL-YEAR HYDROGRAPHS
High
Current
Low
Pre-Development
Flow (cms)
Time (30 Minute Interval, January to January)
Hydrographs taken from XP-SWMM rainfall-runoff simulation, 1988 North Vancouver rainfall data

FIGURE C

APPENDIX B

DOCUMENTATION FOR WORKSHOPS AND WORKING SESSIONS

Brunette Basin Task Group

WATERSHED MANAGEMENT PLAN

OBJECTIVES REPORT

Prepared by:

Dan Ohlson, Principal

Compass Resource Management Ltd.

Prepared for:

Brunette Basin Task Group

September 8, 1997

INTRODUCTION

BACKGROUND

The Brunette Basin Task Group (BBTG) is a multi-stakeholder working group struck under the umbrella of the Greater Vancouver Sewer and Drainage District's *Liquid Waste Management Plan* (LWMP) development process.[1] The group is developing a Watershed Management Plan (the Plan) to integrate both short and long term initiatives among stakeholders within the basin. It is expected that there will be a wide range of management options that will need to be evaluated before the Plan can be prepared, and that a formal approach to option evaluation may be necessary.

In preparation for the option evaluation, the BBTG is establishing an overall goal and management objectives for the Plan, and a preliminary set of performance measures. Compass Resource Management Ltd. and Context Research Ltd. were engaged to facilitate these tasks. This report presents the results of the BBTG's objective-setting process, including some background on objectives and performance measures, a summary of the fundamental objectives for the Plan, and a summary of some preliminary performance measures discussed.

THE OBJECTIVE SETTING PROCESS

Setting objectives for the BBTG Watershed Management Plan involved three tasks:

1) Each BBTG member was interviewed to determine what they felt was important for the Brunette Basin Watershed Management Plan to achieve (i.e., the objectives) and how they might measure Plan achievements (i.e., the performance measures).

2) This input was structured and summarized, and used to develop a draft goal statement and a set of fundamental management objectives for the Plan.

3) A workshop with all BBTG members was held to refine the goal and objectives, and to further discuss the performance measures.

The management objectives outlined below will be further refined as the planning process continues, and as management objectives for the overall *Liquid Waste Management Plan* are developed.

PRIMER ON OBJECTIVES AND PERFORMANCE MEASURES

FUNDAMENTAL OBJECTIVES

In a formal option evaluation process, fundamental objectives become the criteria used to identify and compare different management options. They also provide a framework for setting short term implementation priorities and ensuring coordination with other plans affecting the Basin.

[1] Current membership includes representatives from municipalities, senior government, academic institutions, environmental organizations and the GVS&DD.

When asked to identify the objectives of a management plan, the responses of stakeholders and decision makers can usually be grouped into three categories:

- ***Fundamental Objectives,*** which are the endpoints the plan really hopes to achieve;
- ***Means,*** which are some of the ways or options for achieving them; and
- ***Process Objectives,*** which are related to *how* the plan gets developed and implemented.

Table 1 provides examples of the different types of objectives taken from the BBTG interviews. It is the fundamental objectives that will support a formal option evaluation and decision making process.

Table 1: Objectives - Interview Examples

Interview Statement	Category
"To protect aquatic habitat"	*Fundamental Objective*
"To establish water quality criteria"	*Means*
"To involve the public"	*Process Objective*

CHARACTERISTICS OF GOOD FUNDAMENTAL OBJECTIVES

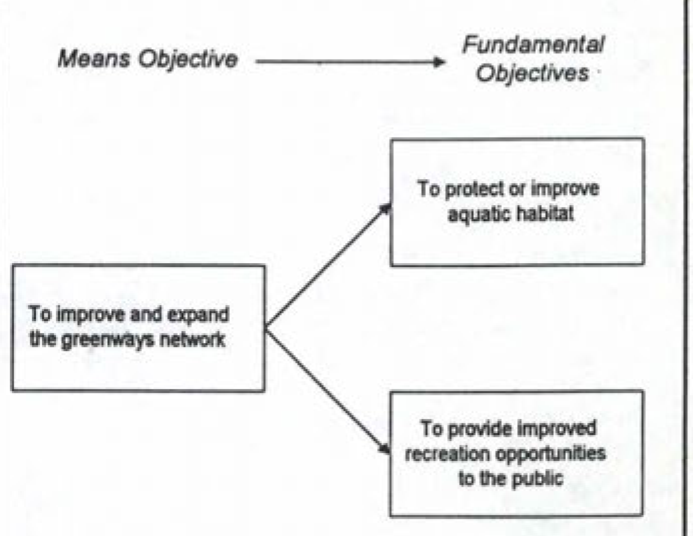
A good set of fundamental objectives will be:

- ***Complete*** — Capturing everything important to the plan;
- ***Concise*** — Manageable in number;
- ***Controllable*** — Within the context and authority of the plan mandate;
- ***Measurable*** — Using performance measures (see next section);
- ***Non-redundant*** — Avoiding double-counting in the evaluation of alternatives.

DISTINGUISHING MEANS AND ENDS

Much of the discussion in the BBTG interviews and workshop focused on means rather than ends or fundamental objectives. Means are really better thought of as management options – that is, ways of achieving the fundamental objectives. This doesn't imply that means are not important. In fact, because one means may contribute toward several fundamental objectives, it can be a critical component of a successful plan (Figure 1).

Figure 1: Means and Ends



Nonetheless, distinguishing means from ends becomes important in the context of a formal evaluation of options. For example, improving and expanding the greenways network (a means) is one way of improving aquatic habitat and recreation opportunities (the ends) (Figure 1). However, there may be other – better – ways of achieving these ends. By separating means and ends, managers are reminded that we don't care about greenways for greenways' sake, only for their contribution to aquatic habitat and recreation opportunities. When options are evaluated, they should be evaluated according to their contribution to aquatic habitat and recreation opportunities, not their contribution to the greenways network.

PERFORMANCE MEASURES

Performance measures are the attributes used to describe the expected impact of management options on the fundamental objectives. Unlike monitoring indicators, which are actual measurements of current conditions, performance measures are up-front predictions of future impacts which are often assessed using models or other forecasting tools[2] (see Table 2).

Performance measures are used by stakeholders and decision makers to evaluate and select among management options during the development of a long term plan. Thus performance measures should always be as closely related to the fundamental objectives of management as possible.

Table 2: Performance Measures and Monitoring Indicators

Attribute	Use
Fecal Coliform Concentration	Possible *Monitoring Indicator* for Water Quality
Likelihood of Fecal Coliform Guideline Exceedences	Possible *Performance Measure* for Aquatic Habitat

CHARACTERISTICS OF GOOD PERFORMANCE MEASURES

Good performance measures are:

- ***Accurate:*** Adequately describing the degree to which options meet the associated objectives;
- ***Practical:*** Meaning the future impact of each management option with respect to the measure can be estimated with a reasonable level of effort;
- ***Understandable:*** To stakeholders and decision makers.

Unfortunately, there are often trade-offs between the accuracy and practicality of performance measures. While objectives can and should be very accurate in describing desired outcomes, compromises may need to be made in the selection of performance measures.

There are three types of performance measures:

[2] In some cases, the same attribute may be used as both a performance measure and a monitoring indicator, the main difference being that the former is a prediction, the latter an actual measurement.

- *Natural:* Those that provide a *direct* measure of the fundamental objective (e.g., present value dollars for a cost objective);
- *Surrogate:* Those that provide a *direct* measure of a closely related objective (e.g., hectares of greenspace for a recreation objective);
- *Proxy:* Those that provide an *indirect* measure of the fundamental objective (e.g., % impervious surface area for a water quality objective, constructed scales[3], etc.).

Whenever possible, it is preferable to use natural performance measures. In practice, surrogate or proxy measures are often used.

While fundamental objectives should not change substantially over time, performance measures may be revisited as new information or forecasting tools become available, or when new alternatives are under consideration that cannot be adequately characterized using an existing performance measure.

RESULTS

GOAL STATEMENT

Following the interviews, a draft goal statement was developed. The challenge in developing a goal statement for the BBTG Watershed Management Plan is to make it broad enough to capture everything that is important, yet concise enough to be meaningful. After further discussion at the workshop, the following goal statement was adopted:

> *Overall Goal for the BBTG Watershed Management Plan*
>
> To protect or enhance the integrity of the aquatic and terrestrial ecosystems and the human populations they support in a manner that accommodates growth and development.

FUNDAMENTAL OBJECTIVES

The first step in structuring the objectives involved grouping interview comments of a similar nature, and separating means from ends. The fundamental objectives are grouped into four main categories (Table 3): i) Environmental, ii) Social, iii) Financial and iv) Learning. Note that they represent fundamental objectives that are relevant to the specific decision context of *urban watershed management* rather than the more limited context of drainage system management, or the broader context of overall regional utility management (which must balance other regional needs such as water supply, etc.).

[3] "Constructed scales" are often used when it is best to measure the achievement of an objective in qualitative terms. For example, a "high, medium, or low" scale can be developed to gauge the level of public satisfaction with a public policy.

Table 3: Fundamental Objectives

1. **Environment**
   1.1 Protect or Enhance Aquatic Habitat
   1.2 Protect or Enhance Terrestrial Habitat
   1.3 Protect or Enhance Biodiversity
2. **Social**
   2.1 Enhance Recreation Opportunities
   2.2 Minimize Health & Safety Impacts
3. **Financial**
   3.1 Minimize Total Societal Costs
   3.2 Minimize Property Damage
4. **Learning**
   Increase Scientific and Management Understanding

ENVIRONMENT

The fundamental environmental objectives of the Plan are to protect or enhance aquatic habitat, terrestrial habitat and biodiversity. While it is possible to view the protection of habitat (terrestrial and aquatic) as a *means* of enhancing biodiversity, all three objectives are maintained at this preliminary stage of the planning process. Some refinement may be necessary to facilitate the option evaluation itself (as final performance measures are set) in order to avoid double-counting.

SOCIAL

Enhancing recreation opportunities and minimizing health and safety impacts related to flooding and poor water quality are the fundamental social objectives of the Plan. A third objective, to improve aesthetics, was deleted during the workshop, as it was felt that it was adequately addressed within the recreation and environmental objectives.

FINANCIAL

The fundamental financial objectives of the Plan are to minimize the total societal cost of Plan implementation (capital, o&m, in-kind), and to minimize any property damage from flooding.

LEARNING

The fundamental learning objective of the Plan is to increase scientific and management understanding with respect to natural systems and the impact of management options on ecosystem function and human health. Better knowledge through learning is really a way of better achieving environmental, social and financial objectives over time. However because of the persistence and pervasiveness of uncertainty with respect to natural systems, learning is increasingly appearing as an explicit fundamental objective of management plans. A learning objective is particularly relevant in this case because this Plan is a pilot that may be replicated in other watersheds, and because it has the active support of research organizations.

OTHER CONSIDERATIONS

During the interviews and the workshop, a number of other potential fundamental objectives were debated. In the end, these were either:

- considered a sub-component of some other fundamental objective (e.g., aesthetics is addressed within recreation);
- recognized as a means rather than an end (e.g., water quality, flood control); or
- treated as a process objective (e.g., improve agency coordination, public education).

There was particular debate over the possible use of two additional fundamental objectives:

Public Education: A well-designed public education and involvement component will be an integral part of the development and implementation of any Plan, regardless of the specific management options adopted (see below). Thus it is recommended that it be treated as a process objective rather than a fundamental objective or endpoint.

Fair Allocation of Costs and Benefits: How to deal with who pays and who benefits from the Plan was not fully resolved at the workshop. It is not included here as a fundamental objective based on two considerations:

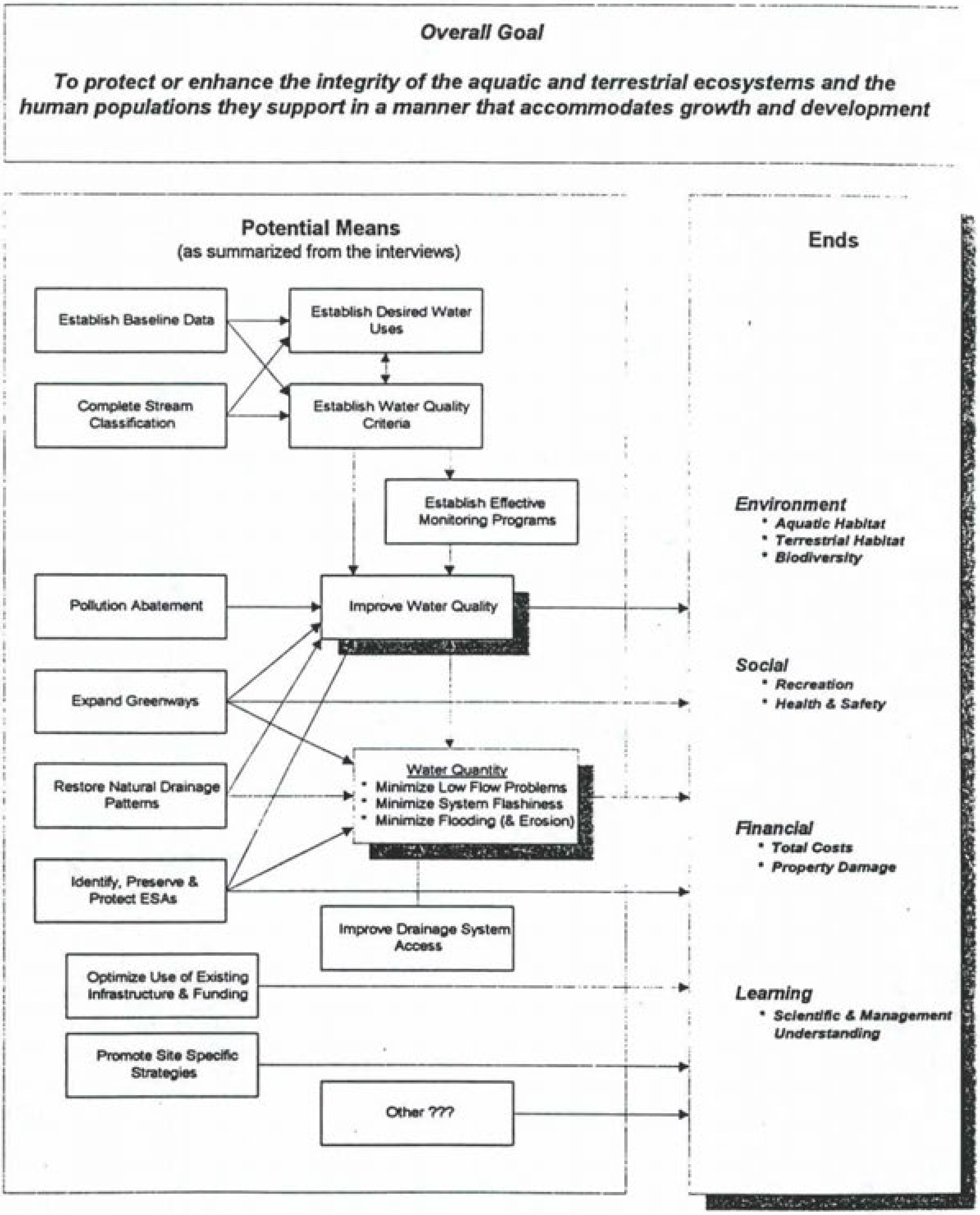
- The issue of actual allocation of costs among municipalities for Regional District programs is likely addressed by the Region's existing cost allocation formula for the Basin. This should be confirmed during the *Situation Analysis*, proposed in the Next Steps section at the end of this report.
- Some participants felt this objective was important because it related to the need to foster inter-agency coordination. Inter-agency coordination is included as a process objective, since, like public education, it will be part of the implementation of any Plan, regardless of the specific management options adopted.

MEANS AND PROCESS OBJECTIVES

Figure 2 shows how a number of important means contribute toward the fundamental objectives.[4] Two means emerged as critically important during the structuring process: "Improving water quality" and various aspects of "water quantity management" (i.e., minimize low flow problems, minimize system flashiness, and minimize flooding). Clearly, the management alternatives that are eventually developed will include strategies related to improving water quality and quantity management.

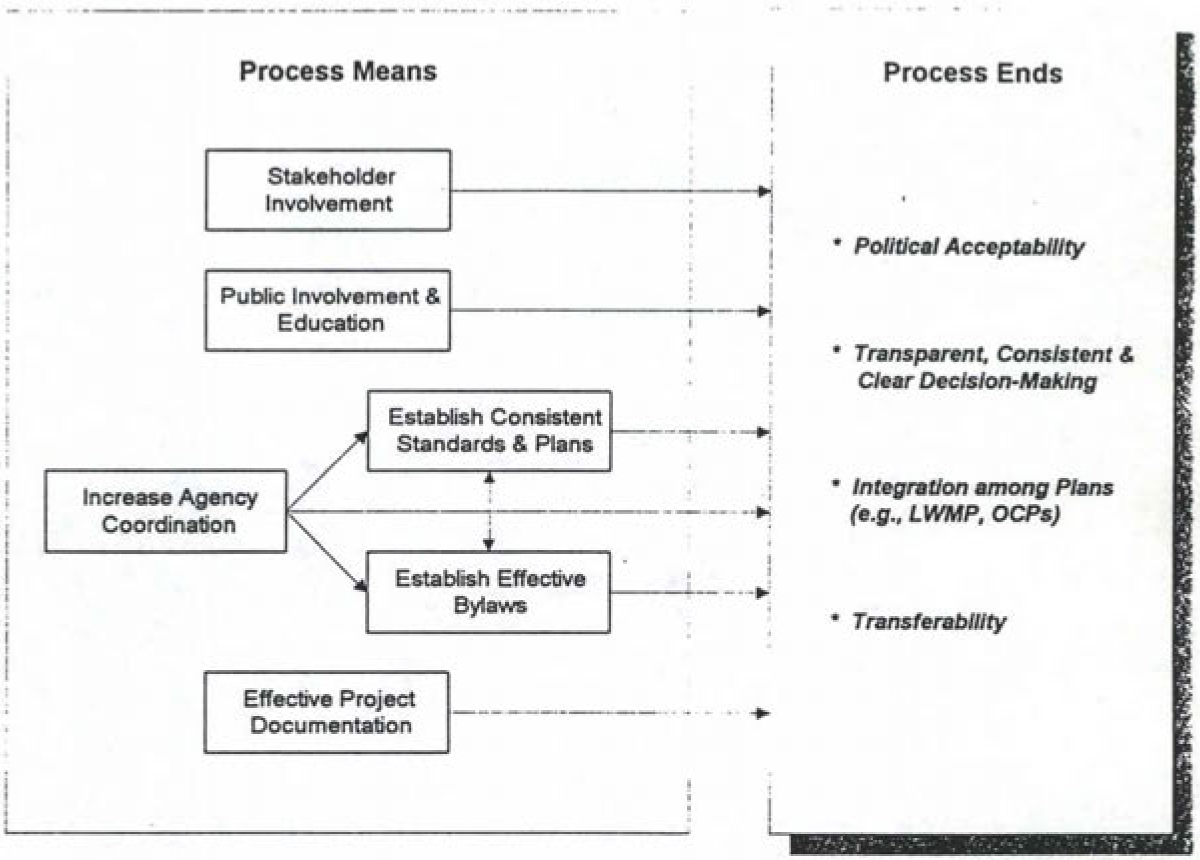
[4] This figure shows only those means identified in the interviews; it is not meant to represent a complete list of all possible means for achieving the fundamental objectives.

Figure 2: Means-Ends Network



Process objectives (Figure 3) relate more to the development and implementation of the Plan itself, rather than the endpoints it hopes to achieve. For example, in order for the Plan to receive final approval, it will be important to address "political acceptability" and "integration among plans" (especially the broader LWMP). Further, public participation will be a component in the development and implementation of any Plan. Like means, process objectives are not necessarily less important than fundamental objectives; they just require different treatment in the planning process.

Figure 3: Process Means-Ends Network



Performance Measures

The interviews and workshop with BBTG members were designed primarily to support the development of a structured set of objectives. A secondary purpose was to get input on potential performance measures. While the final selection of performance measures is beyond the scope of the objective-setting process, the interviews and the workshop were used to generate a set of preliminary performance measures for further consideration. Table 4 summarizes the input received to date.

Through the course of the interviews, ideas for monitoring indicators also emerged (also shown in Table 4). Some data can be used both as performance measures and monitoring indicators, as shown in the table.

Table 4: Preliminary Performance Measures and Monitoring Indicators (as discussed in the workshop)

Objectives	Performance Measures	Monitoring Indicators
1. Environmental		
1.1 Protect or Enhance Aquatic Habitat	• Kilometres/hectares of fisheries habitat • % open channel • Base flow • #, quantity & quality of point sources • Quantity & quality of stormwater runoff (NPS) • % Impervious Area • Traffic intensity • # of cross-connections	• Kilometres/hectares of fisheries habitat • Fish species presence and abundance • Suspended solids • Fecal coliforms • Trace metals • Sediment quality • # source control (or BMP) projects completed • % increase benthic invertebrates
1.2 Protect or Enhance Terrestrial Habitat	• Hectares of green space ⇒ total & contiguous area ⇒ size, shape and number of habitat polygons (edge/total ratio) ⇒ continuity with green space outside of the watershed • Continuous hectares of riparian habitat	• Hectares of green space ⇒ total & contiguous area ⇒ size, shape and number of habitat polygons (edge/total ratio) ⇒ continuity with green space outside of the watershed • Continuous hectares of riparian habitat
1.3 Protect or Enhance Biodiversity	• % natural or functional green space or ecosystem • % increase in habitat for red & blue listed species • % area in wetlands	• Fish, wildlife & plant species presence • Coho/Cutthroat or other ratios • % increase in macro-invertebrates • Flow regime

Table 4: Preliminary Performance Measures and Monitoring Indicators (as discussed in the workshop)

Objectives	Performance Measures	Monitoring Indicators
2. Social		
2.1 Optimize Recreation Opportunities	• # access points • % open channel & open water bodies • Hectares of green space • Length of trails • Diversity of recreation opportunities	• No. of person-days of recreation
2.2 Minimize Health & Safety Impacts	• Expected level & frequency of flood (by location) • Potential # of human safety risk events (e.g., Willingdon Ave. floods) • # of times damage occurs due to floods	• Fecal coliform level (or other water quality indicator) suitable for human contact • Fish flesh toxicity levels • # of times damage occurs due to floods • # emergency responses
3. Financial		
3.1 Minimize Total Costs (Cap + O&M)	• Present Value (PV) of management costs ($) ⇒ from perspective of GVS&DD, Municipalities, Society ?	• Actual costs ($)
3.2 Minimize Property Damage	• Expected value of flood damage ($)	• Actual costs ($)
3.3 Optimize Regional-municipal Cost & Benefit Sharing	• Constructed scale (1-5)	•
4. Learning		
Increase Scientific and Management Understanding	• Constructed scale (1-5)	•

APPLICATION: USING A MULTIPLE ACCOUNT EVALUATION

This section describes how fundamental objectives and performance measures might be applied in the evaluation stage of the planning process using a Multiple Account Evaluation (MAE).

An MAE is a matrix that lists the fundamental objectives (or "accounts") on one axis and management options on the other (Figure 4). The performance of each option with respect to each objective is shown in the cells of the table using the performance measures (e.g., hectares of habitat, present value, etc.).

The value of the MAE format is that it helps to identify key trade-offs, either within a single option or among several options. The decision maker can quickly see trade-offs between financial cost, aquatic habitat, safety risks, and other objectives. The MAE can also highlight options that do not meet critical constraints (e.g., budgets, regulations, etc.) or that are outperformed in all respects by other options.

Once the options are identified and characterized in an MAE, the need for a formal decision making process can be assessed. It may be that one option is clearly better than the others in all respects. In such a case, there is no need for a costly and time consuming decision process. Alternatively, there may be difficult trade-offs that need to be made, necessitating a structured approach. In either case, the MAE provides a useful summary of information to decision-makers and stakeholders.

Figure 4: Multiple Account Evaluation Matrix

Account	Option A	Option B	Option C
Environmental Aquatic Habitat Terrestrial Habitat Biodiversity		*Trade-off among Options*	
Social Recreation Health & Safety		*Trade-off within Options*	
Financial Total Costs Property Damage			
Learning Scientific & Management Understanding			

NEXT STEPS

The establishment of management objectives sets the stage for completing a situation analysis, identifying options and further refining the performance measures. These are briefly outlined below:

- Situation Analysis: The situation analysis will help to assess the current status of management in the Brunette Basin relative to the management objectives developed here. It will involve summarizing and synthesizing existing information regarding key planning issues, critical constraints, regulatory priorities, and data availability (and gaps). The situation analysis should also help to clarify the scope of the options that can be considered under the proposed watershed management plan, and the roles and responsibilities of various members of the BBTG and other implementation partners.

- Option Identification: Based on the situation analysis, an inventory of options should be developed to address the fundamental objectives outlined in this report.

- Performance Measures: The preliminary performance measures summarized in this report can be refined once an inventory of management options is prepared. This will require investigating the availability of relevant data, modelling tools and other estimation or forecasting techniques in order to select performance measures that most accurately reflect performance relative to the objectives, yet can be assessed with a reasonable level of effort.

KWL-CH2M

Kerr Wood Leidal-CH2M Hill Inc.
139 West 16th Street, North Vancouver
British Columbia, Canada V7M 1T3
TEL: 604.985.5361
FAX: 604.985.3705 EMAIL: kwl@kwl.bc.ca

CONSULTING
ENGINEERS
ENVIRONMENTAL
PLANNERS

MEMORANDUM

DATE: April 29, 1998

TO: Stoney Creek Stormwater Management Steering Committee
c/o Lambert Chu, P.Eng., Chairman

CC: Bill Derry, Senior Consultant
Ron Kistritz, Aquatic Ecologist

FROM: K.A. Stephens, P.Eng., Project Manager

RE: **STONEY CREEK STORMWATER MANAGEMENT PLAN**
Working Session #1 on April 22, 1998
Submission of Record of Meeting
Our File No.: 1045.002E

Attached is a *Record of Meeting* for distribution to the members of the Steering Committee. We hope we have fulfilled your expectations in terms of the format and clarity of information presentation.

We enjoyed the meeting. It was time well spent. We found the discussion to be stimulating and productive. We appreciate the insight that you and other Committee members provided. These insights will help us do a better job in developing an appropriate and acceptable stormwater management strategy.

In closing, we look forward to our next meeting on May 11th, at which time we will expand on the storage volume and release rate criteria corresponding to different *MDP Levels*. That meeting may also provide a timely opportunity to review the overall schedule for work program implementation.

KAS/sj
Encl.

T:\1045-002.E\CORRESP\APR22ROM

RECORD OF MEETING

DATE OF MEETING: April 22, 1998

LOCATION: Burnaby Engineering

DURATION: 9 a.m. until 11.25 a.m.
(Note: Informal discussions continued until 12 noon.)

ATTENDED BY:

NAME	ORGANIZATION
Lambert Chu	City of Burnaby
Susan Haid	City of Burnaby
David Palidwor	City of Coquitlam
Julie Pavey	City of Port Moody
Caroline Berka	GVRD
Ed Von Euw	GVRD
Ken Hall	Westwater (UBC)
Bob Brown	SFU
Bob Gunn	BCIT
Marie Belanger	SCEC
Kim Stephens	KWL - CH2M Hill
Chris Johnston	KWL - CH2M Hill
Bill Derry	KWL - CH2M Hill (Washington)
Ron Kistritz	Kistritz Consultants Ltd.

CHAIRED BY: Lambert Chu

MINUTES BY: Kim Stephens

SUBJECT: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT PLAN**
Steering Committee Meeting No. 5
(Working Session #1 with KWL - CH2M Team)
Our File No. 1045-002.E

Attached is a *Record of Meeting* that summarizes key points noted during discussion, and identifies 10 Action Items arising from the discussion.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Working Session #1 with Steering Committee on April 22, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
1.	**Review Action Items Arising from March 13th Meeting.**	
	▸ Confirmation of financial commitment from the project parties.	▸ Coquitlam to provide written confirmation.
	▸ Compilation of reference information: refer to Item #2.	
	▸ Reassessment of water quality sampling strategy: refer to Item #6.	
	▸ Updating of study work program and schedule.	▸ KWL - CH2M to revise to reflect the decisions arising from Working Session #1.
2.	**Compilation of Reference Information**	
	▸ Refer to Attachment #1 for current status.	▸ KWL - CH2M to follow up outside of the meeting.
	▸ The main issue to resolve is GIS mapping.	
3.	**Brunette Basin Watershed Planning Process**	
	▸ The Brunette Basin Task group (BBTG) was formed in 1997 to develop an IWMP (Integrated Watershed Management Plan). The Stoney Creek project is a spinoff from that process.	
	▸ The BBTG is presently developing decision criteria. (Note: previously described as performance measures.) A Draft Report should be available by early June.	
	▸ The BBTG is also developing a public brochure. This may provide an opportunity to highlight the Stoney Creek project. (Note: cross-reference to Item #8.)	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Working Session #1 with Steering Committee on April 22, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
4.	**Goals and Objectives for Stormwater Management** ▸ Refer to Attachment #2 which provided a framework for discussion for Item #4 through Item #7. ▸ The presentation by KWL - CH2M focused on the goal statement in the Terms of Reference: "... develop detailed guidelines and options for runoff control and aquatic enhancement with the goal of preserving the existing streams in their natural state." ▸ The purpose in stimulating discussion was to provide clarity in understanding the implications of each *MDP Level*. Defining questions included: - what do we mean by "preserve"? - what do we mean by "natural"? The answers to these questions shape the strategy for stormwater management. ▸ The challenge is to develop an approach that addresses uncertainty.	
5.	**Applying the Experience of Other Municipalities** ▸ The KWL - CH2M team provided an overview of the results of the research and development program undertaken by the City of Surrey.	▸ KWL - CH2M to conduct a "hydrology working session."
6.	**Approach to Aquatic Habitat Assessment** ▸ Refer to Attachment #3 which summarizes the linkages between Item #4 through Item #6, with emphasis on the significance of *changes in hydrology*. ▸ It is important to tap the expertise of those individuals with hands-on experience regarding the functional aspects of different reaches of the creek channel system. The objective is to compile an accurate picture so that informed decisions can be made regarding possible tradeoffs.	▸ KWL-CH2M to liaise with the SCEC to organize an *Expert Workshop.* ▸ Burnaby Planning to provide contact names for organizations that should possibly be invited to participate.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Working Session #1 with Steering Committee on April 22, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
7.	**Development of a Runoff Quality Assessment Program**	
	▸ The *Briefing Paper* was distributed and the highlights summarized. It was noted that the letter of transmittal can be viewed as an Executive Summary.	▸ KWL - CH2M to proceed with data collection during the May/June period.
	▸ The budget saving (that has resulted from scaling back the scope of the laboratory analysis) will be reallocated to the hydrology component of the study.	
	▸ The SCEC is presently monitoring dissolved oxygen, temperature and pH; and is interested in being proactively involved in future monitoring initiatives.	▸ KWL - CH2M to provide guidance for development of an ongoing volunteer-based monitoring program.
8.	**Development of a Communication Strategy**	
	▸ The Steering Committee does not have a budget for public consultation. Hence, any short-term initiatives will have to be undertaken through the BBTG (which does have a budget for development of a Consultation Plan.)	▸ Steering Committee to arrange for inclusion of an introductory Stoney Creek article in the Brunette Brochure.
	▸ Protocol is important because each municipal partner has to go through its own internal review process once the Steering Committee is clear regarding its objectives.	
	▸ Since the Stoney Creek study has been described as a "pilot program within a pilot program," it is important to publicize the process to foster community involvement over time.	▸ Steering Committee to identify opportunities to raise awareness through existing communications channels (e.g. school newsletters).

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Working Session #1 with Steering Committee on April 22, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
9.	**Scheduling of Future Meetings** ▸ Hydrology Working Session: May 11th (from 2 p.m. to 4 p.m.) at Burnaby Engineering. ▸ Steering Committee Meeting #6: June 9th, from 9 a.m. until 11:30 a.m. ▸ Expert Workshop: latter part of May (i.e. once field work has been completed, and a basemap prepared.	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Summary of Available Information as of Working Session #1 on April 22, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED	
			Yes	No
Ken Hall	Westwater Centre, UBC	• Don McCallum's "Brunette River Watershed, Contaminants Database" data files. • Macdonald, et. al. 1997. Water Quality and Stormwater Contaminants in the Brunette River watershed, B.C., 1994/95. I.R.E., Westwater Research Unit, UBC. • Larkin, G.A., and K.J. Hall. 1998. Hydrocarbon pollution in the Brunette River waterwhed. Wat. Qual. Res. J. Canada. 33(1): 73-94. • Urban Watershed Assessment CD-ROM by Paul Zandbergen.	✓ ✓ ✓ ✓	
Jennifer Atchison	Stoney Creek Environmental Committee	• Goody, K. 1998. A summary of the biophysical and ecological studies of Stoney Creek conducted by the Stoney Creek Environmental Committee. Report prepared for the Stoney Creek Environmental Committee. • Arcinfo Trim Mapping	✓	✓
Susan Haid	Burnaby Planning	• Lougheed Town Centre Plan (1997) • Simon Fraser University Official Community Plan (1996) • Draft Official Community Plan • Burnaby Mtn. Management Plan (i.e., biophysical/ terrestrial study) • Stream mapping of mountain and vegetation polygons. • City of Burnaby. 1998. Review of information in preparation of first Burnaby Mountain Open House. Report prepared by AXYS Environmental Consulting Ltd.	✓ ✓ ✓ ✓ ✓ ✓ ✓	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Summary of Available Information as of Working Session #1 on April 22, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED	
			Yes	No
		• City of Burnaby. 1995. Environmentally Sensitive Areas (ESA) Strategy - An initial program for Burnaby. Memorandum from the Director of Planning and Building to the City Manager. • Gardner Dunster Assoc. Ltd. 1992. The Nature of Burnaby: An Environmentally Sensitive Areas Strategy.	✓ ✓	
Caroline Berka	GVRD	• 3-page tabular summary of information/data on the Brunette watershed that is on-file at the GVRD for: GIS coverages; environmental/water quality/habitat; hydrology/hydraulics/flow; policies/practices/other • Compass Resources Management Ltd. 1997. Brunette Basin Task Group. Watershed Management Plan. Objectives Report. • Arcinfo coverages.	✓ ✓	✓ (Arcinfo coverages)
Julie Pavey	City of Port Moody	• Official Community Plan • Biophysical inventory • Drainage system disks	✓ (Drainage system disks)	✓ (Official Community Plan) ✓ (Biophysical inventory)
David Palidwor	City of Coquitlam	• Report on Stoney Creek ravine • Official Community Plan • North Road Corridor Report • GIS mapping (land ownership, zoning, storm sewers) • Operational issues		✓ ✓ ✓ ✓ ✓
Ed von Euw	GVRD	• Cross-reference to table provided by Caroline Berka		

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Summary of Available Information as of Working Session #1 on April 22, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED	
			Yes	No
Bob Brown	Simon Fraser University	• KWL. 1993. Simon Fraser University - Master Drainage Study. Technical Working Paper No. 1. Drainage System Inventory. • Yarnell, P., and H. Sandmann. 1997. A GAP analysis of the environmental impact assessment for SFU's Burnaby Mountain Development Plan Concept. Regional Planning (REM 642) group project.	✓ ✓	
Bob Gunn	BCIT	• Fish survey data for Still Creek • Students' ESA report • Global Fisheries report on Stoney Creek undertaken for the Ministry of Highways.		✓ ✓ ✓
Lambert Chu	Burnaby Engineering	• Still Creek-Brunette Basin Issues and Proposed Actions (1996 Draft report) • 1995 report to Council on urban stormwater management alternatives • Air photos • Contour mapping (1 m and 2 m intervals) • stream classification mapping by Envirowest • Storm sewer as-builts.	✓ (Still Creek-Brunette report) ✓ (1995 report) ✓ (Contour mapping)	✓ (Air photos) ✓ (stream classification) ✓ (Storm sewer as-builts)

ATTACHMENT #2

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Agenda for Working Session #1 with Steering Committee on April 22, 1998

ITEM	TOPIC AND BRIEFING NOTES
1.	**Goals and Strategic Objectives for Stormwater Management**
	• The report titled *Still Creek - Brunette Basin Issues and Proposed Actions* presents a vision complete with supporting objectives to guide the Stoney Creek study process.
	• The stated goal for the Stoney Creek stormwater management plan is to "preserve the existing streams in their natural state". The objective of the study process is to determine how to make the goal a reality.
	• The report is complemented by a document titled *Watershed Management Plan Objectives Report*, which includes this goal statement: "To protect or enhance the integrity of the aquatic and terrestrial ecosystems and the human population they support in a manner that accommodates growth and development".
	• To select appropriate BMPs, it is first necessary to identify the resources to be protected, the threats to those resources, and the alternative BMPs.
2.	**Applying the Experience of Other Municipalities**
	• The tight budget dictates that we have to be efficient and effective in providing timely knowledge-transfer that will assist the Committee in understanding hydrotechnical issues that have a direct bearing on *how* the above goal statement can be achieved.
	• By defining *MDP Levels*, Figure 2-3 and Table 4-2 as presented in our proposal provides a starting point for conceptualizing "achievable objectives". Table 4-2 is an important document to the extent that it provides the supporting details that explain the concepts illustrated on Figure 2-3.
	• Building on that foundation, we will highlight the results of our Surrey work to demonstrate the customizing and application of storage volume and release rate criteria to achieve varying management objectives within a watershed.
	• Management objectives should reflect and integrate the type of land use, the value of the fisheries resource, and the potential for watercourse erosion. Hence: 1. In existing developed areas, the question to be addressed by the investigative process is this: Is holding the line by means of a *Level 3* approach good enough? 2. In the proposed SFU development area, the question is this: What is required under a *Level 4* approach to maintain the existing "natural" condition?

ITEM	TOPIC AND BRIEFING NOTES
3.	**Development of a Runoff Quality Assessment Program** • Assessment of baseline water quality is a 3-step process, with the first step being development of a sampling strategy. The second step is to implement the sampling program. The third step is to analyze the results.
	• The proposed Water Quality Sampling Program is based on a preliminary review of the existing water quality database, and has been developed in consultation with Ken Hall.
	• The objective of the Water Quality Sampling Program is to provide a meaningful snapshot of existing runoff quality within a cost-effective framework.
	• The proposed sampling program will be carried out during the May/June period, with the objective of capturing a storm event to characterize existing conditions.
	• The results of the runoff quality assessment will provide a basis for selection of BMPs for urban runoff treatment.
4.	**Approach to Aquatic Habitat Assessment** • A date needs to be selected so that we can organize an *Expert Workshop* for a select group of individuals with hands-on experience on the Stoney Creek system. The purpose of the workshop is to do a "brain dump" to provide the study team with complete history on the fisheries resource.
	• The objective of the workshop is to refine the watercourse map (that we will be developing once G&S technical issues are solved) and confirm habitat values and threats on a reach-by-reach basis.
	• This map will be used as a tool in the stormwater management planning process, and will have a bearing on the selection of BMPs.
	• Information on habitat constraints, spawning and rearing habitat, and opportunities for habitat enhancement will be synthesized to define those reaches with the highest priority with respect to fisheries protection. That information will be integrated with the hydrotechnical information in order to designate and characterize reaches for specific stormwater management planning strategies.

ATTACHMENT #3

AQUATIC HABITAT ASSESSMENT AND IMPLICATIONS FOR MANAGEMENT STRATEGIES (Applying the Experience of Other Municipalities)

The Issue: Watercourse erosion resulting from changes in hydrology.

Changes in hydrology remove fish habitat and result in loss of biodiversity and abundance.

The Goal: Develop a strategy for ensuring the *environmental health* of major streamside resources by addressing the *changes in hydrology.*

How: Build on a hydrotechnical foundation that considers all runoff events comprising the annual hydrograph.

Apply the experience of other municipalities that have made major investments in hydrometric data collection and/or environmental monitoring programs.

Findings: Having solid data eliminates speculation.

Peak rates of runoff for infrequent major events are not significantly changed by land use densification, while peak rates for frequent events are very different.

Watercourse erosion (above "natural" rates) is caused by the increased frequency of occurrence of the *frequent events.*

Channel shape is created by a combination of the frequent events and the Mean Annual Flood (note: increases in magnitude with urbanization).

Approach: Focus on the *changes in hydrology* that have resulted from land use changes.

Resolve the erosion issue and a spinoff benefit will be fish habitat protection.

Strategy: Design detention facilities to mitigate the *frequently occurring storms* (i.e. 6 times a year threshold event). If detention is not feasible, and subject to a cost-benefit analysis, bypass peak flows around critical creek sections that have high fisheries values. Alternatively, implement on-site measures to reduce impervious cover.

Detention facilities would serve an "engineering function" to prevent watercourse destabilisation. The spinoff benefit in addressing *changes in hydrology* would be preservation of aquatic habitat and pollutant removal (i.e. the "environmental function").

The Key: Being able to relate stormwater management goals to detention criteria (i.e. unit release rates and storage volumes).

AQUATIC HABITAT ASSESSMENT
AND IMPLICATIONS FOR MANAGEMENT STRATEGIES
(Applying the Experience of Other Municipalities)

The Tool: Stormwater management graphics are science-based and conceptualize key concepts. The objective is to develop a common understanding so that a diverse group of stakeholders can make informed decisions regarding what *may* be achievable.

The concept of *MDP (Master Drainage Plan) Levels* facilitates the process of defining a guiding philosophy, and assessing whether hydrotechnical solutions are also environmentally and politically acceptable.

Background: The concept of a hierarchy of *MDP Levels* makes it possible to categorize the evolution of drainage planning philosophy in recent decades.

Until recently, the approach to stormwater management in British Columbia has typically been shaped by a *Level 2* philosophy: Provide detention storage for major events to maintain peak discharge rates at pre-development levels to achieve the basic goal of protecting property.

Achieving the expanded goal of mitigating frequent storms and preserving aquatic habitat requires a minimum of a *Level 3 MDP* for existing developed areas; and a *Level 4 MDP* for new development areas.

The guiding philosophy for a *Level 3 MDP* is summarized as follows: Implement BMPs that mitigate the effects of redevelopment by *at least* maintaining existing conditions in stream corridors so that there will be no further loss of biodiversity and abundance (i.e. "hold the line").

The guiding philosophy for a *Level 4 MDP* is captured as follows: "Make conditions better" in existing developed areas.

Criteria: Selection of appropriate criteria is fundamental to developing a stormwater management plan.

The challenge is customizing engineering criteria to achieve the goals and objectives for the different *MDP Levels*.

The relevant engineering criteria are the input storm, the release rate(s), and the storage volume. (Note: use rules-of-thumb in lieu of continuous simulation.)

Experience: The *Bear Creek MDP* for the City of Surrey is an application of customized criteria to develop different strategies for different land uses (i.e. by "putting numbers to the concepts").

KWL CH2M

Kerr Wood Leidal-CH2M Hill Inc.
139 West 16th Street, North Vancouver
British Columbia, Canada V7M 1T3
Tel: 604.985.5361
Fax: 604.985.3705 Email: kwl@kwl.bc.ca

CONSULTING ENGINEERS ENVIRONMENTAL PLANNERS

MEMORANDUM

DATE: June 12, 1998

TO: Stoney Creek Stormwater Management Steering Committee
c/o Lambert Chu, P.Eng., Chairman

CC: Bill Derry, Senior Consultant
Ron Kistritz, Aquatic Ecologist

FROM: K.A. Stephens, P.Eng., Project Manager

RE: **STONEY CREEK STORMWATER MANAGEMENT PLAN**
Working Session #2 on June 9, 1998
Submission of Record of Meeting
Our File No.: 1045.002E

Attached is a *Record of Meeting* for distribution to the members of the Steering Committee.

We enjoyed the meeting. We appreciate the insights that you and other Committee members provided. These insights will help us do a better job in developing an appropriate and acceptable stormwater management strategy.

In closing, we look forward to the workshop on August 13th, at which time the committee will review the criteria that we will be developing for making decisions based on the concept of *MDP Levels*.

KAS/sj
Encl.

T:\1045-002.E\CORRESP\JUN9ROM

RECORD OF MEETING

DATE OF MEETING: June 9, 1998

LOCATION: Burnaby Engineering

DURATION: 9:05 a.m. until 11.40 a.m.
(Note: Informal discussions continued until after 12 noon.)

ATTENDED BY:

NAME	ORGANIZATION
Lambert Chu	City of Burnaby
Susan Haid	City of Burnaby
David Palidwor	City of Coquitlam
Caroline Berka	GVRD
Ed Von Euw	GVRD
Bob Gunn	BCIT
Kim Stephens	KWL - CH2M Hill
Chris Johnston	KWL - CH2M Hill
Bill Derry	KWL - CH2M Hill (Washington)
Ron Kistritz	Kistritz Consultants Ltd.

ABSENT:

Julie Pavey	City of Port Moody
Ken Hall	Westwater (UBC)
Bob Brown	SFU
Marie Belanger	SCEC

CHAIRED BY: Lambert Chu

MINUTES BY: Kim Stephens

SUBJECT: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT PLAN**
Steering Committee Meeting No. 6
(Working Session #2 with KWL - CH2M Team)
Our File No. 1045-002.E

Attached is a *Record of Meeting* that summarizes key points noted during discussion, and identifies Action Items arising from the discussion.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Working Session #2 with Steering Committee on June 9, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
1.	**Review Action Items Arising from April 22nd Meeting.**	
	▸ Confirmation of financial commitment from the project parties.	▸ Coquitlam to provide written confirmation.
	▸ Update study work program and schedule.	▸ Refer to memo dated May 5, 1998.
	▸ Compile reference information.	▸ Refer to Attachment #1.
	▸ Conduct a hydrology working session.	
	▸ Liaise with Burnaby Planning and the SCEC to organize an expert workshop on fisheries issues.	
	▸ Proceed with runoff quality data collection in May/June.	
	▸ Provide guidance for development of an ongoing volunteer-based monitoring program.	▸ To be addressed in the final report.
	▸ Arrange for inclusion of an introductory Stoney Creek article in the Brunette Brochure.	▸ (Space not available.)
	▸ Identify opportunities to raise awareness of the Stoney Creek pilot program for integrated stormwater management.	
2.	**Results of Hydrology Working Session**	
	▸ The focus was on two graphics that illustrate the 'changes in hydrology' for a 'typical year' as a result of land-use densification.	
	▸ There has been a paradigm-shift in urban hydrology in terms of the function of detention facilities being mitigation of the 'frequently occurring storms.'	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Working Session #2 with Steering Committee on June 9, 1998

<table>
<tr><th>ITEM</th><th>TOPIC AND DISCUSSION HIGHLIGHTS</th><th>REQUIRED ACTION</th></tr>
<tr><td></td><td>
Proposed minimum criteria for detention facility sizing in the Stoney Creek watershed are:
<table>
<tr><th>CONDITION</th><th>INPUT EVENT [1]</th><th>RELEASE RATE</th></tr>
<tr><td>Redevelopment</td><td>Q_2</td><td>50% Q_2 [2]</td></tr>
<tr><td>New Development</td><td>Q_5</td><td>50% Q_2 [3]</td></tr>
</table>
[1] For post-development condition.
[2] For original single-family residential condition.
[3] For pre-development land-use condition.
</td><td>
Refer to Record of Meeting dated May 11, 1998.
</td></tr>
<tr><td>3.</td><td>
Status of Water Quality Monitoring Program
Refer to the handout dated June 1, 1998.
</td><td></td></tr>
<tr><td>4.</td><td>
Application of Aquatic Habitat Assessment

The Expert Workshop on May 27th provided an opportunity for the SCEC to participate in the study process, and enabled the Project Team to validate and update information on fisheries resources and values.
The next step is to apply what has been learned from the workshop process to develop management objectives for the watershed.
The Brunette Vision provides the benchmark for the study because the goal is to protect and enhance the environment while accommodating growth. This leads to the question: "What needs to be done, and what tradeoffs would be required?"

</td><td></td></tr>
</table>

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Working Session #2 with Steering Committee on June 9, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
	▸ Guiding principles are suggested as follows: 1. Protect the best first. 2. Enhance where have opportunities. 3. Mitigate for development. ▸ The graphic conceptualizing *MDP Levels* is a decision-making tool that also illustrates the 'time-line concept':	
	▸ A workshop would be desirable to establish decision-making criteria and evaluate options for stormwater management. This would also provide an opportunity to develop the framework for a program that could then be presented to an expanded group.	▸ Schedule an all-day workshop for August 13, 1998.
5.	**Significance of NE Secondary School Project** ▸ The evolving criteria for detention facility sizing have been presented to the School Team to allow the project to go forward. ▸ The project would seem to provide an opportunity for a pilot program to demonstrate the application of innovative stormwater control measures.	

MINIMUM TIME HORIZON	IDENTIFICATION OF MINIMUM GOALS
Within 20 Years	The goal should be to reach *Level 3* (i.e. as an "average" condition).
After 20 to 50 Years	Building on success in the first 20 years, strive for *Level 4* in the decades following.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Working Session #2 with Steering Committee on June 9, 1998

ITEM	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
6.	**Summary and Next Steps** ▸ The next milestone is the August 13th Workshop. The objective is to evaluate the implications of each *MDP Level* and make choices based on a set of decision-making criteria that are to be circulated in advance of the Workshop.	▸ Circulate preliminary information on decision-making criteria prior to the August 13th Workshop.

Please advise either Lambert Chu or Kim Stephens of any desired refinements to this *Record of Meeting.*

T:\1045-002.E\CORRESP\JUN9ROM

ATTACHMENT #1

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Summary of Available Information as of Working Session #2 on June 9, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED	
			Yes	No
Ken Hall	Westwater Centre, UBC	• Don McCallum's "Brunette River Watershed, Contaminants Database" data files. • Macdonald, et. al. 1997. Water Quality and Stormwater Contaminants in the Brunette River watershed, B.C., 1994/95. I.R.E., Westwater Research Unit, UBC. • Larkin, G.A., and K.J. Hall. 1998. Hydrocarbon pollution in the Brunette River waterwhed. Wat. Qual. Res. J. Canada. 33(1): 73-94. • Urban Watershed Assessment CD-ROM by Paul Zandbergen.	✓ ✓ ✓ ✓	
Jennifer Atchison	Stoney Creek Environmental Committee	• Goody, K. 1998. A summary of the biophysical and ecological studies of Stoney Creek conducted by the Stoney Creek Environmental Committee. Report prepared for the Stoney Creek Environmental Committee. • Arcinfo Trim Mapping	✓ ✓	
Susan Haid	Burnaby Planning	• Lougheed Town Centre Plan (1997) • Simon Fraser University Official Community Plan (1996) • Draft Official Community Plan • Burnaby Mtn. Management Plan (i.e., biophysical/ terrestrial study) • Stream mapping of mountain and vegetation polygons. • City of Burnaby. 1998. Review of information in preparation of first Burnaby Mountain Open House. Report prepared by AXYS Environmental Consulting Ltd.	✓ ✓ ✓ ✓ ✓ ✓ ✓	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Summary of Available Information as of Working Session #1 on April 22, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED Yes	No
		• City of Burnaby. 1995. Environmentally Sensitive Areas (ESA) Strategy - An initial program for Burnaby. Memorandum from the Director of Planning and Building to the City Manager. • Gardner Dunster Assoc. Ltd. 1992. The Nature of Burnaby: An Environmentally Sensitive Areas Strategy.	✓ ✓	
Caroline Berka	GVRD	• 3-page tabular summary of information/data on the Brunette watershed that is on-file at the GVRD for: GIS coverages; environmental/water quality/habitat; hydrology/hydraulics/flow; policies/practices/other • Compass Resources Management Ltd. 1997. Brunette Basin Task Group. Watershed Management Plan. Objectives Report. • Arcinfo coverages.	✓ ✓ ✓	
Julie Pavey	City of Port Moody	• Official Community Plan • Biophysical inventory • Drainage system disks	✓ (Official Community Plan) ✓ (Drainage system disks)	✓ (Biophysical inventory)
David Palidwor	City of Coquitlam	• Report on Stoney Creek ravine • Official Community Plan • North Road Corridor Report • GIS mapping (land ownership, zoning, storm sewers) • Operational issues	✓ (North Road Corridor Report)	✓ (Report on Stoney Creek ravine) ✓ (Official Community Plan) ✓ (GIS mapping) ✓ (Operational issues)
Ed von Euw	GVRD	• Cross-reference to table provided by Caroline Berka		

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Summary of Available Information as of Working Session #1 on April 22, 1998

STEERING COMMITTEE MEMBER	ORGANIZATION	IDENTIFICATION OF REFERENCE MATERIAL	INFORMATION RECEIVED	
			Yes	No
Bob Brown	Simon Fraser University	• KWL. 1993. Simon Fraser University - Master Drainage Study. Technical Working Paper No. 1. Drainage System Inventory.	✓	
		• Yarnell, P., and H. Sandmann. 1997. A GAP analysis of the environmental impact assessment for SFU's Burnaby Mountain Development Plan Concept. Regional Planning (REM 642) group project.	✓	
Bob Gunn	BCIT	• Fish survey data for Still Creek	✓	
		• Students' ESA report	✓	
		• Global Fisheries report on Stoney Creek undertaken for the Ministry of Highways.	✓	
Lambert Chu	Burnaby Engineering	• Still Creek-Brunette Basin Issues and Proposed Actions (1996 Draft report)	✓	
		• 1995 report to Council on urban stormwater management alternatives	✓	
		• Air photos		✓
		• Contour mapping (1 m and 2 m intervals)	✓	
		• stream classification mapping by Envirowest		✓
		• Storm sewer as-builts.		✓

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

Kerr Wood Leidal-CH2M Hill Inc.
920 - 475 W. Georgia Street, Vancouver, BC V6B 4M9 Canada
TEL: 604-684-3282; FAX: 604-684-3292

MEMORANDUM

DATE: August 26, 1998

TO: Stoney Creek Steering Committee

NAME	AFFILIATION	FAX #
Lambert Chu	Burnaby Engineering	294-7425
Jennifer Atchison	Stoney Creek Env. Committee	420-9105
Caroline Berka	GVRD	436-6714
Ed von Euw	GVRD	436-6714
Bob Brown	SFU	291-3189
Bob Gunn	BCIT	432-9046
Kevin Connery	Burnaby Planning	294-7220
Ken Hall	Westwater	822-9250
Dave Palidwor	Coquitlam	933-6099
Julie Pavey	Port Moody	469-4550

CC: Bill Derry, CH2M, Senior Consultant
Chris Johnston, KWL, Project Engineer
Ron Kistritz, Aquatic Ecologist

FROM: Kim A. Stéphens, Project Manager, CH2M

RE: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT**
Results of August 12th Workshop with Steering Committee
CG&S File #112V25464 and KWL File # 1045.002

On behalf of Lambert Chu, we take pleasure in forwarding a copy of the record of the August 12th Workshop for your review in advance of the September 11th working session.

ASSESSMENT OF WORKSHOP OUTCOME

The workshop was successful in terms of energizing the Committee and developing a common understanding of the elements of a stormwater management plan, with the result that the discussion was far-reaching and extremely productive. Of real significance, the committee members focussed on how the technical decisions are made when developing a plan, and made a rather unique request in asking the study team to put down on paper its 'thinking process.' (The simple answer is: Our synergy is such that we 'feed' off each other.)

In view of the outcome of the workshop, we take this opportunity to comment on the noticeable change in direction since the *Study Initiation Meeting* on March 13, 1998. At the end of that meeting, our understanding was that the Committee wished to minimize the time spent in working sessions with the Study Team. It now appears that the Committee wishes to maximize the spent that it spends with the team.

APPROACH TO REPORT PRESENTATION

The change in direction requires a different style of report than may have been originally envisioned in the *Terms of Reference*. This presents some interesting challenges. On the one hand, considerable work needs to be done at a detailed level to ensure confidence in the technical findings. On the other hand, the report has to be written at a fairly sophisticated level to capture the decision-making process.

In summary, the foregoing do have budget implications. While we are endeavouring to tailor our remaining effort to complete the study within budget, the reality is that our costs will in fact exceed the authorized budget. From a cost control perspective, then, it is important that we bring this study to closure as soon as possible. We therefore hope that the Committee can make some final decisions at the September 11th workshop.

In advance of the workshop, we will forward an information package to provide a focus for further discussion. This will include a preliminary outline plus a write-up on the 'decision process'

CLOSING REMARKS

In closing, please note that the attached *Record of Meeting* scratches the surface in terms of summarizing everything that was discussed on August 12th. Hopefully, we have captured all the relevant points. If not, we welcome feedback from the Committee so that the attachment accurately reflects the meeting.

RECORD OF MEETING

DATE OF MEETING: August 12, 1998

LOCATION: Burnaby Engineering

DURATION: 9:05 a.m. until 3:15 p.m.
(Note: Informal discussions continued until after 4:00 p.m.)

ATTENDED BY:

NAME	ORGANIZATION
Lambert Chus	City of Burnaby
Kevin Connery	City of Burnaby
David Palidwor	City of Coquitlam
Julie Pavey	City of Port Moody
Caroline Berka	GVRD
Ed Von Euw	GVRD
Bob Gunn	BCIT
Jennifer Atchinson	SCEC
Kim Stephens	CH2M
Bill Derry	CH2M
Chris Johnston	KWL
Ron Kistritz	Kistritz Consultants Ltd.

ABSENT:

Ken Hall	Westwater (UBC)
Bob Brown	SFU

CHAIRED BY: Lambert Chu

MINUTES BY: Kim Stephens

SUBJECT: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT**
Steering Committee Meeting No. 7
(Working Session #3 with KWL-CH2M Team)
CG&S File No. 112V25464 and KWL File No. 1045-002.E

Attached is a *Record of Meeting* that summarizes key points noted during discussion, and identifies action items arising from the discussion.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Workshop with Steering Committee on August 12, 1998

ITEM	TIME SLOT	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
1	0910 - 0915	**Overview of Workshop Objectives** (Lambert Chu) • Provided a perspective on the challenge in developing a master plan that protects property and allows economic land use while sustaining natural systems. • Review the proposed 3-part format for the workshop (i.e. Program Results; Elements of a Plan; Decision-Making). • Identify the workshop objectives, and provide a context relative to the overall Brunette initiative.	• Identify achievable/acceptable elements of a *Level 3 MDP*.
2	0915 - 0925	**Integrated Stormwater Management: What Does that Really Mean?** (Kim Stephens) • Provided an overview on the evolution of drainage planning philosophy, and the implications for 'sustainable development' as articulated in Official Community Plans. • Highlighted the hydrotechnical and environmental components of an integrated strategy and how they provide a 'road map' for the workshop process. • Reviewed the four factors limiting the ecological values of urban streams, and their relative significance in developing an appropriate BMP strategy.	
3	0925-0945	**Results of Hydrotechnical Component of Work Program** (Kim Stephens and Chris Johnston) • Provided an overview on the approach to peak flow modelling for the extreme events, and the hydraulic adequacy of existing drainage facilities (under both existing and future land use conditions). • Elaborated on modelling methodology that utilized 100 discretized areas, routed the runoff through EXTRAN (to provide a 'movie'), involved validation of the model under both summer and winter conditions, and established that the watershed has 23% impervious area. • Presented the elements of a possible master plan for drainage facility upsizing/upgrading to ensure adequate conveyance capacity for Q_{100} and provide for fish passage.	• Complete a risk management assessment that considers both the hydraulic and physical adequacy of culvert installations.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Workshop with Steering Committee on August 12, 1998

ITEM	TIME SLOT	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
4	0945 – 1010	**Results of Runoff Quality Component of Work Program** (Chris Johnston & Ron Kistritz) • Distinguished between the two components of the monitoring program (baseline and storm events); and highlighted the significant findings for each component. • Presented the time-series graphs of turbidity versus discharge, and turbidity versus TSS (Total Suspended Solids), and concluded that turbidity is primarily caused by urban runoff rather than by stream-bed erosion. • Commented on what the turbidity findings mean for fish health in the creek system, with emphasis on the duration of exposure and concentration being a key to assessing the stress effect on fish.	
5	1010 – 1020	**Results of the Aquatic Habitat Assessment Component of Work Program** (Ron Kistritz and Bill Derry) • Developed a common understanding of the aquatic resources to be protected, and the threats to those resources. • Presented a graphic that reflects the reach-by-reach findings as validated/updated through the Expert Workshop process, with the best fisheries values being in the section between the Lougheed Highway and the Brunette confluence. • Discussed how the reach-by-reach findings can be applied to develop management objectives for watershed sub-areas.	
6	1020 – 1025	**Defining a Shared Vision: Six Steps to Making and Implementing Quality Decisions** (Bill Derry) • Referred to the flowchart that illustrates a proven approach to consensus-building and decision-making for complex issues, and highlighted the importance of feedback loops. • Elaborated on how shared achievable goals lead to action and implementation. • Emphasized the importance of reaching consensus on achievable goals and realistic expectations for Stoney Creek using the overarching framework provided by the Brunette initiative.	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK
Record of Workshop with Steering Committee on August 12, 1998

ITEM	TIME SLOT	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
	1025 – 1035	**REFRESHMENT BREAK**	
7	1035 – 1230	**Elements of a Concept Plan for Stoney Creek Integrated Stormwater Mangement** (Presentation by Kim Stephens and Chris Johnston; facilitated discussion by Bill Derry) • Reviewed the graphic that conceptualizes *MDP Levels* and that also illustrates the 'time-line concept' for decision-making. • Based on the results of the Aquatic Habitat Assessment, presented elements of a plan for achieving Level 3 (Hold the Line) and then transitioning to Level 4 (Improve Conditions). • Elaborated on the elements of the plan, and facilitate a discussion on their achievability and implications.	• Assess how much the community is willing to pay to achieve environmental objectives. • Consider the possibility of combining elements from both MDP levels. • Specify a storage volume that must be provided by SFU and allow SFU to decide how best to provide that volume. • Ensure that any diversion plan for Stoney includes a facility at the confluence with the Brunette to protect the resources in the Brunette. • Identify and incorporate possible havitat enhancement elements on the plan. • Refer to 'strategy' rather than to 'plan' when presenting the elements.
	1230 – 100	LUNCH BREAK	
8	100 - 305	**Decision-Making Criteria for Evaluation and Selection of Stormwater Management Choices** (facilitated discussion by Bill Derry) • Noted that the *Brunette Objectives Report* provides a starting point for evaluating Objectives, Performance Measures and Monitoring Indicators. • Reviewed and fine-tuned the evaluation decision criteria for 3 scenarios as customized for Stoney Creek to make preliminary decisions regarding achievable goals for stream management (Refer to attachment). • Discussed the need for a transparent process for information presentation that shows how the Steering Committee made its choices.	• Reassess the format for information presentation • Expand the matrix to reflect the decisions for each reach of channel. • Develop a way to capture the thought processes of the study team.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Record of Workshop with Steering Committee on August 12, 1998

IEM	TIME SLOT	TOPIC AND DISCUSSION HIGHLIGHTS	REQUIRED ACTION
9	305 – 315	**Concluding Remarks and a Look Ahead** (Lambert Chu) • Summarized the 'required actions' arriving from the discussion, and provided a perspective on what was accomplished in the workshop session • Identified 'next steps' in terms of bringing closure to the study process, and integrating the findings in the Management Plan for the Brunette Watershed • Scheduled the next working session for Friday, September 11th. It may be an all-day meeting	

TABLE 1

STRATEGY FOR STONEY CREEK STREAM MANAGEMENT

Scenario A - Status Quo

Continue current recommended management practices (Status Quo). Community values urban stream system for open space and aesthetic values. Water quality and flooding must not degrade downstream conditions. Accept that current trends in declining biological resources may continue.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	Increases to peak and duration of peak flows are partially mitigated.	Are regulations enforced? Trends of increased peak flows and duration of peak flows continue. Monitoring incomplete.	Enforce existing policies and regulations for flow control from new development. Investments in capital facilities such as regional detention ponds and bank stabilization projects.
Riparian Corridor	Riparian corridors are partially protected.	Are regulations enforced? Trends of riparian loss continue at present rate.	Enforce existing policies and regulations for riparian setbacks for new development
Aquatic Habitat	Loss of aquatic habitat is limited.	Are regulations enforced? Trends in aquatic habitat loss continue at present rate.	Enforce existing policies and regulations for stream protection
Water Quality	Declines in water quality are minimized.	Are regulations enforced? Trends in water quality decline continue.	Enforce existing policies and regulations for water quality for new and existing development
Fish	Further declines in fish populations are minimized.	Returning spawning salmon counts continue trend. Stream supports trout.	Enforce existing regulations
Economic Sustainability	Economic growth and development continue	Economic growth continues to reflect overall economy.	None.

TABLE 2

STRATEGY FOR STONEY CREEK STREAM MANAGEMENT

Scenario B - Hold the Line

Hold the line in the face of growth and downward trends. Community values stream system for its biological functions in addition to open space and aesthetic values. Community accepts that trout and hatchery supported salmon populations are a reasonable management goal and is willing to invest additional effort and funds to achieve this.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	No change in peak or duration of runoff from storm events.	Stream monitoring demonstrates that neither frequency nor duration of peak flows has increased. No net loss of forest cover. Effective empervious surface between 12% and 25%.	Requires increased standards for retention of forest, infiltration and detention of runoff, factors of safety and measures to address changes not captured by regulatory system. Zero discharge of runoff from 6-month return storm. No loss of wetlands or wetland function.
Riparian Corridor	No net loss.	Annual measurements and ground inspection reveals no net loss of riparian buffer width or vegetation. At least 60% of the stream corridor has a buffer of 30 meters on each side.	Requires stronger regulation for buffers, limits on clearing for existing properties, enforcement and compensation mechanisms.
Aquatic Habitat	No loss of habitat	Annual monitoring reveals that pool/riffle ratios, percent of fines in the sediment, large organic debris, and benthic index of biotic integrity do not deteriorate. Use Module 2 of the advanced stream habitat survey interpretation sheet and Module 4 of the invertebrate survey interpretation sheet.	Requires stronger regulation for hydrology, riparian buffers and water quality. Requires annual program working with volunteers to construct habitat structures. No loss of wetlands or wetland functions.
Water Quality	No decline in water quality.	Water quality monitoring indicates that water quality does not deteriorate from existing conditions. Water quality is not toxic to fish.	Requires increased regulations and increase in educational program for residents. Increased enforcement of water quality violations. Capital improvements to contain spills and treat runoff from commercial areas. Response program for rapid containment and clean-up of spills.
Fish	No decline in fish populations, mixture of wild and hatchery fish.	Annual fish counts indicate that successfully spawning pairs and juvenile survival rates of salmon do not decline. Trout populations are self-sustaining and stable.	All of the above.
Economic Sustainability	Economic growth and development continue	Economic growth continues to reflect overall economy.	Work to assure regulations are consistent across the lower mainland.

TABLE 3

STRATEGY FOR STONEY CREEK STREAM MANAGEMENT

Scenario C - Improve Conditions

Enhance aquatic conditions and accommodate growth. Community places high value on stream system and self-sustaining wild salmon populations. Community is willing to make substantial investments to achieve this goal recognizing that this goal may not be achievable.			
Goal	**Objective**	**Measurable Criteria**	**Actions Required to Achieve Goal**
Hydrology	Frequency and duration of peak flows is reduced	Annual review of monitoring data demonstrates that the peaks and durations of flows resulting from a six month and annual return interval storm event are not increased and that there is no increase in the peak flows from more frequent storms.	All of the above plus zero discharge of runoff from storms up to the two year return event storm. Capital improvements to increase regional detention and infiltration. Potential capital improvements to by-pass peak flows through entire system. Aggressive program to plant evergreen trees throughout the watershed.
Riparian Corridor	Additional riparian corridor is protected	At least 60 % of the riparian corridor is protected with a 30 metre buffer of undisturbed vegetation	All of the above plus aggressive program to purchase developed riparian areas, remove structures and re-establish native vegetation in buffers.
Aquatic Habitat	Additional aquatic habitat is created.	Pool/riffle ratio is approximately 50/50, percent of fines in sediment is less than 15%, the Benthic Index of Biotic Integrity is at least 35. Use Module 2 of the advanced stream habitat survey interpretation sheet and Module 4 of the invertebrate survey interpretation sheet.	All of the above plus aggressive program to construct and maintain aquatic habitat structures. Restore lost wetland functions.
Water Quality	Water quality improves	Water quality meets Provincial and Federal guidance for all parameters.	All of the above plus aggressive program to build small scale treatment facilities at major stormwater outfalls.
Fish	Fish abundance and diversity improves, self sustaining populations of only wild fish.	Salmon and trout spawning counts return to 10% (say) of historic levels adjusted for ocean and harvest conditions. Hatchery releases are stopped.	All of the above plus aggressive education program that discontinues program of raising salmon in the classroom and substitutes a program addressing benthic organisms.
Economic Sustainability	Economic growth and development continue	Economic growth continues to reflect overall economy. Public is willing to accept increases in regulations, development costs and fees necessary to achieve goal.	Work to assure regulations are consistent across neighboring local jurisdictions.

KWL CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

Kerr Wood Leidal-CH2M Hill Inc.
920 - 475 W. Georgia Street, Vancouver, BC V6B 4M9 Canada
TEL: 604-684-3282; FAX: 604-684-3292

MEMORANDUM.

DATE: September 3, 1998

TO: Stoney Creek Steering Committee

NAME	AFFILIATION	FAX #
Lambert Chu	Burnaby Engineering	294-7425
Jennifer Atchison	Stoney Creek Env. Committee	420-9105
Caroline Berka	GVRD	436-6714
Ed von Euw	GVRD	436-6714
Bob Brown	SFU	291-3189
Bob Gunn	BCIT	432-9046
Kevin Connery	Burnaby Planning	294-7220
Ken Hall	Westwater	822-9250
Dave Palidwor	Coquitlam	933-6099
Julie Pavey	Port Moody	469-4550

CC: Bill Derry, CH2M, Senior Consultant
Chris Johnston, KWL, Project Engineer
Ron Kistritz, Aquatic Ecologist

FROM: Kim A. Stephens, Project Manager, CH2M

RE: **STONEY CREEK INTEGRATED STORMWATER MANAGEMENT**
Handout Package for September 11th workshop with Steering Committee
CG&S File #112V25464 and KWL File # 1045.002

On behalf of Lambert Chu, we take pleasure in forwarding a copy of the 'handout package' for your review in advance of the September 11th workshop on *Strategy Development for Stoney Creek Integrated Stormwater Management*.

Stoney Creek Stormwater Management Study
Working Session No. 5 with Steering Committee

BRIEFING NOTES ON STRATEGY DEVELOPMENT for STONEY CREEK INTEGRATED STORMWATER MANAGEMENT

September 11, 1998

Our File No. 112V25464

Kerr Wood Leidal – CH2M Hill Inc
A Jointly Owned Company of CH2M Gore & Storrie Ltd and Kerr Wood Leidal Associates Ltd

BRIEFING NOTES ON STRATEGY DEVELOPMENT FOR STONEY CREEK STORMWATER MANAGEMENT (Working Session No. 5 with Steering Committee)

Agenda for September 11th

Attached is an agenda that comprises six items. The program is structured in two parts as follows:

- **Part A:** The project team will make presentations with the objective of engaging the Committee in a discussion of a 6-step process for making decisions that are transparent.
- **Part B:** Building on Part A, the objective is to reach consensus on the selection of stormwater management choices to achieve *Level* 3 (i.e. Hold the Line) and over time transition to *Level* 4 (i.e. Improve Conditions).

Presentation of Study Findings

The second attachment is the proposed *Table of Contents* for our pending report. Our objective in submitting it is to review our proposed approach to information presentation so that the Committee will be fully informed, as well as have a timely opportunity for input.

Given that a primary focus of the Committee is on the decision-making process, also attached is a first draft of Chapter 3 of the report. The chapter is titled *Conceptual Framework for Decision Process.* We hope this chapter fulfills the information needs of the Committee as articulated during the August workshop.

As noted previously, the writing of this report presents some interesting challenges. Considerable work needs to be done at a detailed level to ensure confidence in the technical findings, yet the focus of the report is on concepts and 'bigger picture' issues rather than the technical details. It must also be written at a fairly sophisticated level to capture the essence of the decision-making process.

At the August workshop, there was a noteworthy discussion as to whether the product of this study is a *Strategy* or a *Plan*. Our judgement is that the report title should incorporate the word strategy. Hence, the suggested title is *Integrated Stormwater Management Strategy for Stoney Creek Watershed.*

We refer you to the graphic that we included in our proposal submission and that we presented at the August workshop. The graphic in question is the one that illustrated five boxes, and characterized the study output as an *Integrated Stormwater Management Strategy and Master Drainage Plan.* We hope this background aids the Committee in deciding how it wishes to capture the essence of the study.

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Agenda for Workshop with Steering Committee on September 11, 1998

ITEM	TIME SLOT	TOPIC AND BRIEFING NOTES	REQUIRED ACTION
0	0845 – 0900	**Organize and Prepare**	
1	0900 – 0905	**Opening Remarks** (Lambert Chu) • Comment on the August 12th workshop • Review the workshop agenda • Identify the desired outcome	
2	0905 - 0920	**Elements of a Concept Plan for Integrated Stormwater Management** (Kim Stephens, Ron Kistritz, & Chris Johnston) • Re-cap the results of the aquatic habitat assessment and the implications for a watershed and stream corridor management strategy • Review the graphic that presents elements of a plan for achieving Level 3 (Hold the Line) and then transitioning to Level 4 (Improve Conditions) • Summarize the preliminary decisions arising from the August workshop, and comment on the direction provided by the Committee	
3	0920 – 1045	**Application of 6-Step Decision Process for Strategy Development and Evaluation** (Bill Derry) • Refer to the graphic that illustrates a proven 6-step process for making and implementing quality decisions • Refer to Chapter 3 of the report and discuss the application of each of the 6-steps to the Stoney Creek decision-making process • Review the *Decision Matrix* (i.e. Table 3-4 in Chapter 3) that has been developed for Stoney Creek, and refine as may be required	
	1045 – 1050	**REFRESHMENT BREAK**	
4	1050 – 1150	**Strategies for Achieving Shared Environmental Goals, and Selection of Plan Elements for Integrated Stormwater Management** (Facilitated discussion by Bill Derry) • Reach consensus on the issue of flow diversion versus on-site detention at SFU • Identify the combinations of elements (as presented under Item #2) to form the basis for a Level 3 and/or a Level 4 plan • Reach consensus on the selection of an *MDP Level* to carry forward as a recommendation for endorsement by each Council	

INTEGRATED STORMWATER MANAGEMENT PLAN FOR STONEY CREEK

Agenda for Workshop with Steering Committee on September 11, 1998

ITEM	TIME SLOT	TOPIC AND BRIEFING NOTES	REQUIRED ACTION
5	1150 – 1220	**Presentation of Study Findings** (Facilitated discussion by Kim Stephens) • Finalize the selection of achievable elements of a concept plan that will be supported by the community • Review and obtain the concurrence of the Committee for the proposed *Table of Contents* for presentation of the study findings • Discuss the communication strategy for reaching the target audience(s)	
6	1220 – 1230	**Concluding Remarks** (Lambert Chu) • Summarize the 'required actions' arising from the discussion, and provide a perspective on what has been accomplished in the workshop session • Identify 'next steps' in bringing closure to the study process, and integrating the findings in the Management Plan for the Brunette Watershed	

CITY OF BURNABY

STONEY CREEK STORMWATER STEERING COMMITTEE

INTEGRATED STORMWATER MANAGEMENT STRATEGY FOR STONEY CREEK WATERSHED

DRAFT FOR REVIEW

SEPTEMBER 1998

CGS File No. 112V25464
KWL File No. 1045.002D

KERR WOOD LEIDAL - CH2M HILL INC
A Jointly Owned Company of CH2M Gore & Storrie Ltd. and Kerr Wood Leidal Associates Ltd.

TABLE OF CONTENTS

LIST OF APPENDICES

1.3 Defining a Shared Vision for Community Livability

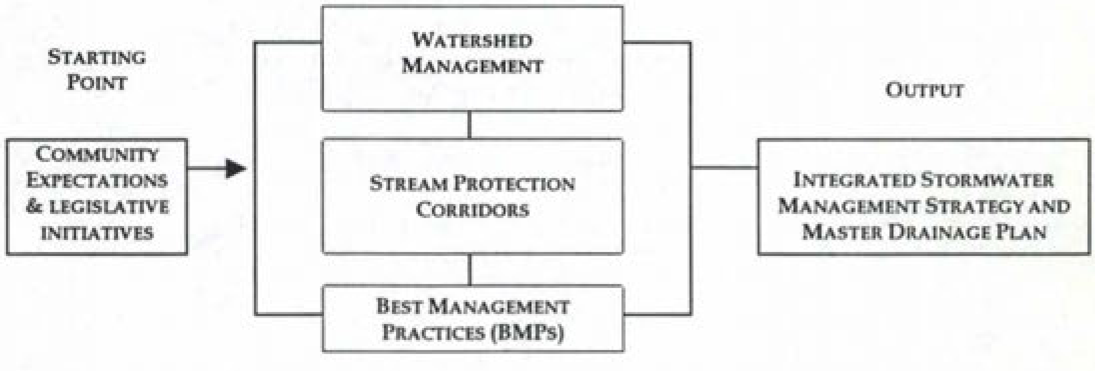
The challenge is to develop an *Integrated Stormwater Management Strategy* that is practical, cost-effective, and achievable. The following hierarchy provides a benchmark for referencing the goals and objectives of the master drainage and environmental planning processes.

Level	Description of Initiative	Purpose
1	Provincial Legislation	Provide local government with enabling tools
2	Official Community Plan	Define community goals and livability objectives
3	Brunette River Watershed Management Plan	Establish priorities for natural resource sustainability
4	Stoney Creek Stormwater Management Plan	Protect property and ecosystems

Ensuring that the strategy is realistic and supported by the community requires an understanding of what may be achievable in terms of environmental protection.

1.4 Framework for Integrated Master Planning

The fundamental question that must be addressed by the master drainage planning process is this: *How can the ecological values of stream corridors and receiving waters be protected and enhanced by a Master Drainage Plan, while at the same time the plan is facilitating land development and/or redevelopment?* Given this starting point, the following diagram conceptualizes the basic components of an ecosystem-based approach to stormwater management:



To select appropriate management strategies it is first necessary to identify the resources being protected, the threats to those resources, and the alternative management strategies.

3. CONCEPTUAL FRAMEWORK FOR DECISION PROCESS

3.1 A Perspective

Identification of Shared Community Goals

In the 1990s, it is essential that a stormwater management strategy have the support of the community. To this end, Figure 3-1 conceptualizes the essence of the stakeholder involvement process. This model is also applicable to the Steering Committee process, because a variety of perspectives need to be integrated in reaching consensus on "shared achievable goals" for watershed and stream corridor management.

Six Steps to Making and Implementing Quality Decisions

Figure 3-1 illustrates a proven approach to decision-making for complex issues, and complements Figure 3-2. This flowchart emphasizes the need for a deliberate process that involves stakeholders in developing a shared vision. By incorporating feedback loops, this process also incorporates opportunities for *adaptive management*.

If the public and the elected officials have a shared vision for integrated stormwater and natural resource management, funding and implementation are far more likely to follow. With participation of the regulatory agencies in the visioning process, senior governments are far more likely to support a municipality's efforts and less likely to impose burdensome requirements.

Integration with Master Planning Process

Figure 3-1 actually integrates two concepts for consensus-building and goal setting. The two parts of Figure 3-1 are described as follows:

- **Hierarchal Process**: The left side illustrates the flow path for successfully bringing forward a major initiative. First, there has to be a perceived need. This then establishes the goals in developing a strategy. Finally, implementation requires public support in order to generate political action.
- **Iterative Process**: The right side illustrates the six steps required to efficiently make and implement quality decisions. All too often engineers jump directly to *Step #4* (which is to collect data) without first having defined the problem and obtained commitment to the shared goals.

To be effective, a strategy must be based on a clear definition of the shared goals, and realistic expectations for achieving them. Our approach to the Stoney Creek stormwater management study will be grounded in a commitment to this type of participatory decision process.

EDUCATION *leads to* → UNDERSTANDING

PARTICIPATION *leads to* → OWNERSHIP

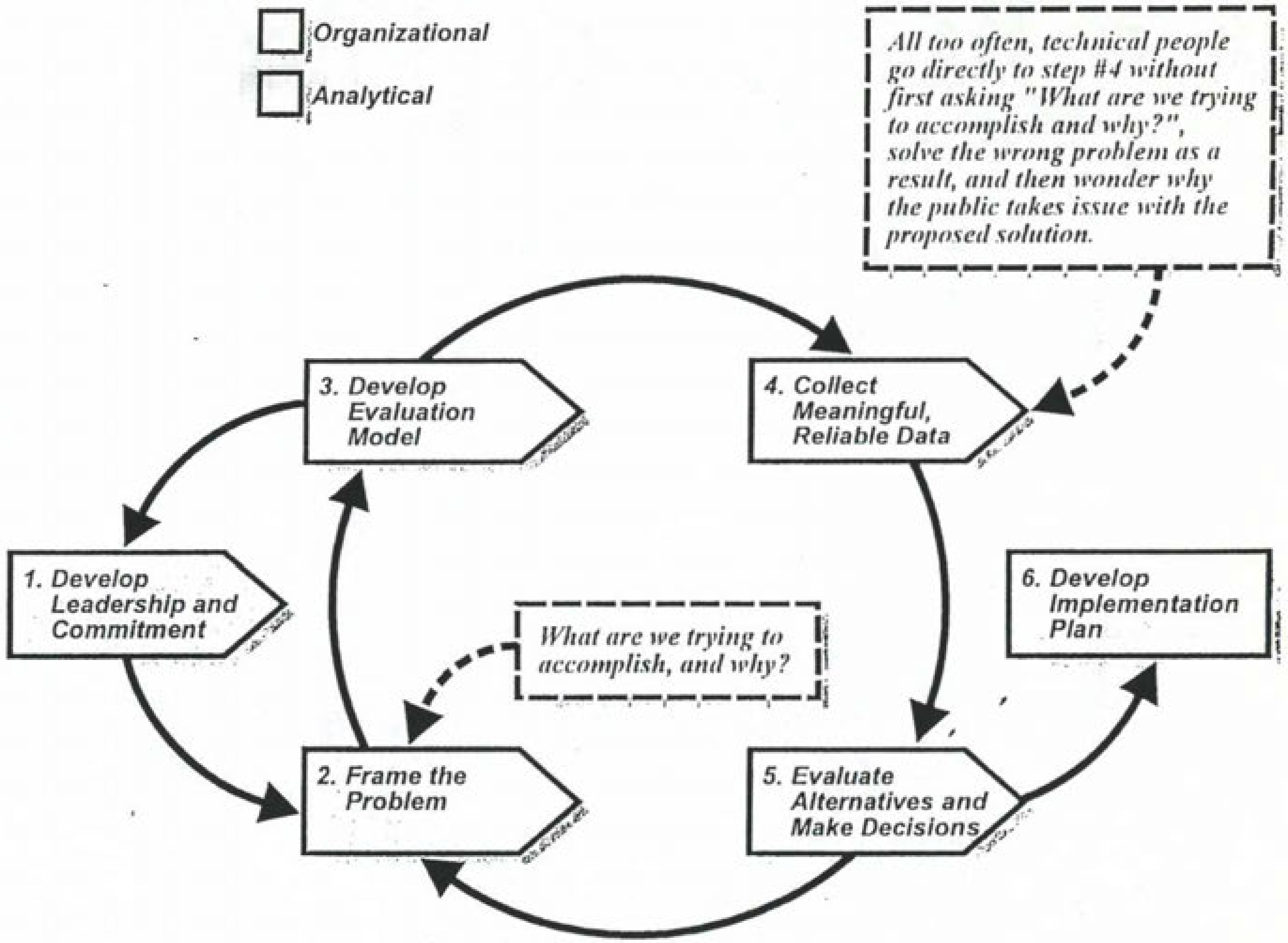
SHARED ACHIEVABLE GOALS *leads to* → ACTION & IMPLEMENTATION

THE ESSENCE OF PROACTIVE STAKEHOLDER INVOLVEMENT

FIGURE 3-1

1045-002X1FIG1-3.CDR

Flow Chart For Master Planning Process



KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

Six Steps To Making And Implementing Quality Decisions

Figure 3-2

3.2 Application of the Six-Step Process to Stoney Creek

Introduction

This section describes how the 'six-step process' as illustrated on Figure 3-2 applies to the decision process used for development of the *Stoney Creek Stormwater Management Strategy*. Each step is described in detail in the sub-sections that follow.

Step One: Assure Leadership and Commitment to the Decision and the Process

Leadership and commitment have been established through the formulation of a project steering committee and approval of the process by the elected officials from each of the jurisdictions.

The steering committee comprises representatives from each of the municipalities with jurisdiction in the watershed, the GVSDD District and community representatives. Engineers and planners are present from the municipalities. Each jurisdictions elected officials have demonstrated commitment by approving and providing funding for the process.

The Committee process provides an interim vehicle for gauging community values and community support with respect to a guiding philosophy for watershed and stream corridor management.

Step Two: Frame the Problem

The *Stoney Creek Stormwater Management Strategy* is being developed within the context of the overall *Brunette Basin Watershed Management Plan*. It has been called a "pilot within a pilot" project. Stoney Creek has been recognized as the most productive remaining sub-watershed within the Brunette Watershed and therefore worthy of the highest environmental protection.

Under existing management programs, the environmental values of the stream are declining. The numbers of successfully spawning and rearing salmon are declining. Flooding and erosion has increased. Water quality monitoring has shown high levels of nutrients, suspended solids, coliform bacteria and other pollutants. There are significant development activities occurring in the Stoney Creek sub-watershed that threaten the environmental values of the stream.

A plan is necessary to provide environmental protection while allowing continued development and redevelopment to occur. The land use patterns are well established and the Stoney Creek watershed is substantially developed. Thus, major changes in land uses are not realistic and are not addressed in this study.

The primary focus of this study is to identify Best Management Practices (BMPs), on-site requirements for new development and redevelopment, capital improvements and agency programs needed to achieve the desired goal.

Step Three: Develop Value Model and Formulate Alternatives

Goal Statement

The Task Group for the *Brunette Basin Watershed Management Plan* has developed a draft goal statement and corresponding objectives. These are drawn from the various OCPs for the participating jurisdictions. The OCPs are the official statements of policy and reflect the community values. The overall goal for the Brunette is stated below:

> **To protect or enhance the integrity of the aquatic and terrestrial ecosystems and the human populations they support in a manner that accommodates growth and development.**

This goal is equally appropriate for Stoney Creek. Another way to express this goal in terms of its application to Stoney Creek is to state that: The goal is to develop a master plan that protects property and allows economic land use while sustaining natural systems.

Fundamental Objectives

The set of objectives as formulated by the Brunette Task Group is presented below in four groupings:

CATEGORY	OBJECTIVES
Environmental	• Protect or enhance aquatic habitat • Protect or enhance terrestrial habitat • Protect or enhance bio-diversity
~~Special~~ Objectives Social	• Optimize recreational opportunities • Minimize health and safety impacts related to flooding and water quality
Financial Objectives	• Minimize life cycle costs • Minimize property damage • Optimize regional-municipal cost and benefit sharing
Learning Objective	• Increase scientific and management understanding

Certain objectives are assumed to be mandatory minimal requirements. These include achieving the standards for protection from flooding and addressing water quality issues that are toxic to fish or humans.

Alternatives must address these issues within the Stoney Creek watershed and must not simply pass the problem downstream. Beyond this, the selection of the level of environmental protection or enhancement becomes a local decision. The local decision must balance the benefits and costs to the local and regional community.

Identification and Evaluation of Alternatives

To facilitate the evaluation, a series of planning scenarios has been developed that corresponds to potential levels of environmental protection as follows:

- **Scenario A:** Status Quo Strategy for Stream Management
- **Scenario B**: Hold the Line and Accommodate Growth Strategy for Stream Management
- **Scenario C:** Enhance Equatic Conditions and Accommodate Growth Strategy for Stream Management

These tables are described in Tables 3-1 through 3-3. With differing levels of effort and investment, the jurisdictions managing the Stoney Creek watershed could achieve varying levels of environmental protection.

The tables describe these levels, specific objectives to achieve the levels, measurable criteria to test achievement, and actions needed to achieve the desired results. Looking ahead to Chapter 7, Figure 7-1 illustrates the major capital elements corresponding to these scenarios.

Factors Limiting the Ecological Values of Urban Streams

Within the subject of environmental protection, a primary issue is the question of achievable levels of sustainable fish populations. Research has shown that urban development significantly impacts the abundance and diversity of fish populations. In order of importance, the primary impacts to fish in urbanizing watersheds are due to:

- changes to hydrology,
- loss of riparian corridors,
- loss of physical habitat and
- water quality degradation.

Tables 3-1 through 3-3 are organized to address these issues. These tables expand on the previously introduced objectives by providing performance measures for each of these issues, and include a summary of the actions needed to achieve the stated level of environmental protection.

Application of Master Planning Levels

Three levels of potential environmental protection for fish are presented. These levels correspond to the 'planning levels' introduced in Chapter 1 (i.e. Table 1-2) and illustrated on Figure 2-3. Key points to note are highlighted below:

- *Level Two* (Table 3-1) would maintain the status quo for government programs. Existing regulations and procedures would continue and habitat values would continue their present downward trends.
- *Level Three* (Table 3-2) would sustain existing environmental conditions but would require additional programs and financial costs.
- *Level Four* (Table 3-3) would enhance existing aquatic environmental conditions but at substantial additional costs for regional facilities and increased requirements for on-site facilities to manage stormwater from new development.

Decision makers must choose from these levels by balancing the environmental, social and financial benefits against the financial costs and the risks of not achieving the selected objectives.

The decision process to choose the level of environmental protection will be an iterative one and may result in selection of a combination of protection levels for differing portions of the watershed.

Application of Decision-Making Matrix

The decision criteria are the objectives. To decide which level of environmental protection is preferred, the decision maker must determine how well each scenario achieves each objective and balance the trade-offs and conflicts. For example, the highest level of environmental protection will have the highest environmental benefits but will require the highest financial costs to developers and the community.

Each objective and each scenario is presented in matrix form in Table 3-4. With the matrix, each criterion can be considered for each scenario and the results can be visualized, compared and recorded. In workshop format, the Stoney Creek steering committee must evaluate and discuss each alternative and select a preferred approach.

For convenience and ease of discussion, the three scenarios introduced previously are referred to as 'strategies' in Table 3-4.

Table 3-I: Status Quo Strategy for Stream Management
(Scenario A: Status Quo)

Continue current recommended management practices. Community values urban stream system for open space and aesthetic values. Water quality and flooding must not degrade downstream conditions. Accept that current trends in declining biological resources may continue.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	Increases to peak and duration of peak flows are partially mitigated.	Are regulations enforced? Trends of increased peak flows and duration of peak flows continue. Monitoring incomplete.	Enforce Existing policies and regulations for flow control from new development. Investments in capital facilities such as regional detention ponds and bank stabilization projects.
Riparian Corridor	Riparian corridors are partially protected.	Are regulations enforced? Trends of riparian loss continue at present rate.	Enforce Existing policies and regulations for riparian setbacks for new development
Aquatic Habitat	Loss of aquatic habitat is limited.	Are regulations enforced? Trends in aquatic habitat loss continue at present rate.	Enforce Existing policies and regulations for stream protection
Water Quality	Declines in water quality are minimized.	Are regulations enforced? Trends in water quality decline continue.	Enforce Existing policies and regulations for water quality for new and existing development
Fish	Further declines in fish populations are minimized.	Returning spawning salmon counts continue trend. Stream supports trout.	Enforce existing regulations

Table 3-2: Hold the Line and Accommodate Growth Strategy for Stream Management
(Scenario B: Hold the Line)

Hold the line in the face of growth and downward trends. Community values stream system for its biological functions in addition to open space and aesthetic values. Community accepts that trout and hatchery supported salmon populations are a reasonable management goal and is willing to invest additional effort and funds to achieve this.

Goal	Objective	Measurable Criteria	Actions Required to Achieve Goal
Hydrology	No change in peak or duration of runoff from storm events.	Stream monitoring demonstrates that neither frequency nor duration of peak flows has increased. No net loss of forest cover. Effective impervious surface between 12 and 25%.	Requires increased standards for retention of forest, infiltration and detention of runoff, factors of safety and measures to address changes not captured by regulatory system. Zero discharge of runoff from 6 month return storm. No loss of wetlands or wetland function.
Riparian Corridor	No net loss.	Annual measurements and ground inspection reveals no net loss of riparian buffer width or vegetation. At least 60% of the stream corridor has a buffer of 30 meters on each side.	Requires stronger regulation for buffers, limits on clearing for existing properties, enforcement and compensation mechanisms.
Aquatic Habitat	No loss of habitat	Annual monitoring reveals that pool/riffle ratios, percent of fines in the sediment, large organic debris and benthic index of biotic integrity do not deteriorate. Use module 2 of the advanced stream habitat survey interpretation sheet and module 4 of the invertebrate survey interpretation sheet.	Requires stronger regulation for hydrology, riparian buffers and water quality. Requires annual program working with volunteers to construct habitat structures. No loss of wetlands or wetland functions.
Water Quality	No decline in water quality.	Water quality monitoring indicates that water quality does not deteriorate from existing conditions. Water quality is not toxic to fish.	Requires increased regulations and increase in educational program for residents. Increased enforcement of water quality violations. Capital improvements to contain spills and treat runoff from commercial areas. Response program for rapid containment and clean-up of spills.
Fish	No decline in fish populations, mixture of wild and hatchery fish.	Annual fish counts indicate that successfully spawning pairs and juvenile survival rates of salmon do not decline. Trout populations are self-sustaining and stable.	All of the above.

Table 3-3: Enhance Aquatic Conditions and Accommodate Growth Strategy for Stream Management

(Scenario C – Improve Conditions)

Enhance Aquatic Conditions and accommodate growth. Community places high value on stream system and self-sustaining wild salmon populations. Community is willing to make substantial investments to achieve this goal recognizing that this goal may not be achievable.			
Goal	**Objective**	**Measurable Criteria**	**Actions Required to Achieve Goal**
Hydrology	Frequency and duration of peak flows is reduced	Annual review of monitoring data demonstrates that the peaks and durations of flows resulting from a six month and annual return interval storm event are not increased and that there is no increase in the peak flows from more frequent storms.	All of the above plus zero discharge of runoff from storms up to the two year return event storm. Capital improvements to increase regional detention and infiltration. Potential capital improvements to by-pass peak flows through entire system. Aggressive program to plant evergreen trees throughout the watershed.
Riparian Corridor	Additional riparian corridor is protected	At least 60 % of the riparian corridor is protected with a 50 metre buffer of undisturbed vegetation	All of the above plus aggressive program to purchase developed riparian areas, remove structures and re-establish native vegetation in buffers.
Aquatic Habitat	Additional aquatic habitat is created.	pool/riffle ratio is approximately 50/50, percent of fines in sediment is less than 15%, the Benthic Index of Biotic Integrity is at least 35.	All of the above plus aggressive program to construct and maintain aquatic habitat structures. Restore lost wetland functions.
Water Quality	Water quality improves	Water quality meets Provincial and Federal guidance for all parameters.	All of the above plus aggressive program to build small scale treatment facilities at major stormwater outfalls.
Fish	Fish abundance and diversity improves, self sustaining populations of only wild fish.	Salmon and trout spawning counts, at best, return to 10% of historic levels adjusted for ocean and harvest conditions. Hatchery releases are stopped.	All of the above plus aggressive education program that discontinues program of raising salmon in the classroom and substitutes a program addressing benthic organisms.

Table 3-4: Decision Criteria to Select Strategies for Stream Management

Objectives or Decision Criteria	How important is this criterion?	Strategy A: Status quo, continued declines in fish*	Strategy B: Hold the line, sustain trout and hatchery salmon*	Strategy C: Enhance habitat, sustain wild salmon*
Protect or enhance biodiversity*	very important	low	medium	high
Protect or enhance aquatic habitat*	very important	low	medium	high
Protect or enhance terrestrial habitat	moderate importance	low	medium	high
Enhance recreation opportunities	moderate importance	low	medium	high
Minimize health and safety impacts	very important	high	high	high
Minimize total costs	very important	high (no change in existing costs)	medium (increased costs)	low (high cost)
Minimize property damage	very important	medium	high	high
Increase scientific and management understanding	least important	medium	high	high
Increase opportunity for public learning	least important	medium	high	high

* See Tables 3-1, 3-2 and 3-3 for refinement of these decision criteria and for more detailed descriptions of the scenarios.

Step Four: Collect Meaningful, Reliable Data

The first step in analyzing potential environmental benefits is to assess the current habitat values and water quality within the system. This has been accomplished through the use of an expert panel workshop, field investigations, water quality and quantity monitoring and modeling of the stream flows. The results of these analyses are described in subsequent chapters but summarized here.

Looking ahead to Chapter 5, Figure 5-1 describes the relative aquatic habitat values of each reach within the Stoney Creek system. This figure shows where the highest value habitat is presently found and describes some of the limiting factors to fish habitat.

Analysis of this figure shows that the highest value habitat in the system is the reach at the bottom of the system (between the Lougheed Highway and the confluence with the Brunette) and within Tributary #3. Limits to habitat include barriers to fish passage, bank erosion along the main channel resulting from increased flows and loss of riparian corridor.

Step Five: Evaluate Alternatives and Make Decisions

Application of Professional Judgement

Using the data available, the next step is to evaluate the alternatives on the basis of the identified criteria and make decisions. It is anticipated that the decisions may reflect a combination of elements from the three scenarios and that they may be applied differently to each subwatershed. Because of the limited data available and the complexities of dealing with natural systems, each decision-maker must rely in part on their own informed, professional judgement to evaluate the alternatives.
At this point in the process, it is important to check back with leadership and other stakeholders and assure that they are still committed to the need, process, values and recommendations of the study.

Verification of Leadership and Commitment

The Project Steering Committee is now at this step. Decisions must be made regarding selection of preferred alternatives. Then each participant must return to their respective constituencies and verify leadership and commitment. If necessary, adjustments may be required to the objectives, criteria or weighting factors and the evaluation process repeated. Or, additional data may be needed to reduce uncertainty regarding the outcomes.

Step Six: Develop Implementation Plan

This step is beyond the scope of the present study, and will be developed by the staff of the participating jurisdictions.

3.3 Elements of a Concept Plan for Stormwater Management

A Perspective on Understanding Fundamental Concepts

Reaching consensus on what elements of a master plan may be achievable requires a full and proper understanding of fundamental concepts related to:

- The impact of land use changes on hydrology, with emphasis on what 'zero runoff' from forested land actually means, and the implications for SFU.
- The vastly different approaches to mitigating and/or containing *frequently occurring* and *extreme* runoff events once forested land is urbanized.

Calibrated hydrologic models supplemented by monitoring programs provide enhanced insights into watershed response to rainfall under a range of antecedent conditions over the seasonal cycle. Development of an 'integrated stormwater management strategy' involves a multi-level thinking process that builds on the foundation provided by those insights.

Distinction between Conventional MDPs and Integrated Management Plans

The primary thrust of a conventional MDP (Master Drainage Plan) is on mitigating major peak flow events (e.g. Q100), with particular emphasis on the conveyance adequacy of culverts and trunk sewers. Hence, the reference to an MDP being the *hydrotechnical component* of an integrated plan.

The hydrotechnical component can be viewed as one level of thinking, and is seemingly the most straightforward to address because it essentially involves a comparison of 'design flows' versus 'rated capacities'. This simplifies the task of preparing a plan of proposed remedial measures.

Further to the last paragraph, the hydrotechnical component was dealt with early in the workshop process so that the Committee could then focus its efforts on those levels where participatory decision-making was required.

Integrated stormwater management involves the application of human values in making choices related to protection and preservation of ecosytems. Thus, a challenge for the Committee is reaching consensus on 'shared values' that will be supported by the public so that an affordable stormwater management plan for Stoney Creek can in fact be implemented.

Presentation of the elements of a concept plan requires interaction with the Steering Committee so that the implementation and affordability implications of a *Level 3 MDP* can be explored, explained, and hopefully resolved.

The Starting Point for Strategy Development

A plan was presented to the Committee at the August workshop that illustrated the possible elements of an *integrated stormwater management strategy*. The aquatic resources to be protected influence the selection of choices for consideration by the Committee. Based on the findings of the aquatic habitat assessment, critical observations that provide a starting point for plan development are highlighted as follows:

- **Watercourse Condition:** The Stoney Creek system may be described as being in a state of noticeable decline since considerable bank erosion and channel instability are evident in the main stem.

- **Fisheries Resource Values:** The reaches from the confluence with the Brunette River to the Loughheed Highway are rated as having the best fisheries value. The next best reach is the north branch of Tributary #3.

Given that 'changes in hydrology' is the most significant of the four factors impacting on the environmental values of urban streams, and in view of the limited opportunities for regional stormwater detention lakes within the Stoney Creek watershed, this means that the only other options for mitigating changes in hydrology would be a combination of peak flow bypasses and on-site impervious area reduction initiatives.

Concept for Interception of Peak Flows from Simon Fraser University

In the mid-1960s, an interceptor storm sewer was constructed down Gagliardi Way to the south branch of Tributary #3. The concept for accommodating proposed residential development within the Ring Road, while at the same time mitigating earlier 'changes in hydrology', is to extend the interceptor system. The main elements are identified as follows:

- **Off-Site Drainage System:** Install a branch interceptor up the south half of the Ring Road to serve the new development area.

- **Outfall Location:** Re-direct the discharge from the Gagliardi Way sewer into Tributary #2 (instead of #3), and then into a second interceptor sewer system.

- **Ecosystem Protection:** Bypass the lower reaches of the main stem so that the best fisheries values can be preserved and protected.

The rationale for each element was explained in the workshop. A key consideration is that the concept makes effective use of existing infrastructure. Another key consideration is that it serves a two-fold purpose: mitigates a problem created by existing urbanization in the western part of the drainage basin; and allows new development to proceed.

Identification of Opportunities for Regional Stormwater Detention

For the western half of the drainage basin, the focus of a stormwater management strategy is on peak flow bypasses (as discussed on the previous page). For the eastern half, on the other hand, there may be opportunities for regional detention at two possible locations. Feedback on the feasibility and practicality of developing each site was solicited from the Committee during the workshop.

Optimizing Willingness to Pay versus Environmental Consequences

The purpose in presenting the elements of a Concept Plan was to stimulate discussion among the Committee members regarding the capital cost implications and achievability of the 'hold the line' goal of a *Level 3 MDP*. While definitive cost estimates were not available for the workshop, the Committee was at least able to judge the order-of-magnitude of proposed elements.

From the perspective of the Project Team, it was helpful that the facilitated discussion provided a basis for assessing the likely acceptability of various elements.

Identification of Inter-Municipal Partnership Issues

An issue that may need to be highlighted soon through the political reporting process is the impact of re-development and land use densification in Coquitlam on the fisheries resource within Burnaby.

Unless an impervious area reduction program can be successfully implemented in conjunction with re-development, the only potential site for regional stormwater detention is situated within Burnaby. This raises the issue of the upstream municipality taking responsibility for funding construction of facilities in a downstream jurisdiction.

Integration with Brunette Watershed Management Plan

As noted previously, the Stoney Creek process is viewed as a 'pilot program within a pilot program' because the intention is to apply the 'Stoney Creek model' to other sub-catchments within the Brunette River system. Similarly, the 'Brunette model' could be applied to other urban drainage systems within the region.

Given this frame-of-reference, the strategy for Stoney Creek must be compatible with the overall strategy for the Brunette. An holistic approach is therefore necessary when evaluating the acceptability of stormwater management choices: for example, discharging the bypassed peak flows into the Brunette, because there may be a concern regarding the possible impact on fisheries habitat in the Brunette.

3.4 Workshops: A Forum for Feedback and Knowledge Transfer

Communication holds the key to developing effective partnerships. Workshops and working sessions provide a forum for the communication process. The objective is to stimulate the creative thinking of the workshop participants in addressing this fundamental question: *What are we trying to accomplish, and why?* To date, the communication process for the Stoney Creek study has involved three workshops and three working sessions. The focus of each workshop is highlighted as follows:

- **First Workshop - Customizing Hydrologic Criteria:** In early May 1998, the engineering representatives on the Steering Committee met with members of the Project Team to reach consensus on the selection of engineering criteria for sizing stormwater detention facilities. The concept of *MDP Levels* was embraced in principle for sizing ponds as a function of release rates.

- **Second Workshop - Documentation of Aquatic Habitat Knowledge:** In late May 1998, members of the Project Team met with the *Stoney Creek Environmental Committee* to acquire undocumented biophysical information on the Stoney Creek system and to generally validate/update documented information that has been collected in the past. The information was compiled reach-by-reach.

- **Third Workshop - Evaluation and Selection of Achievable Elements of a Concept Plan:** In mid-August 1998, the Steering Committee met with the Project Team to evaluate possible options and solutions to urban runoff issues, and in so doing contribute to development of an acceptable stormwater management strategy to protect the aquatic resources in Stoney Creek.

The three workshops were complemented by three half-day working sessions with the Committee. The latter provided timely opportunities for progress reporting by the Project Team, and for the Committee to provide feedback and direction.

3.5 Summary of Findings

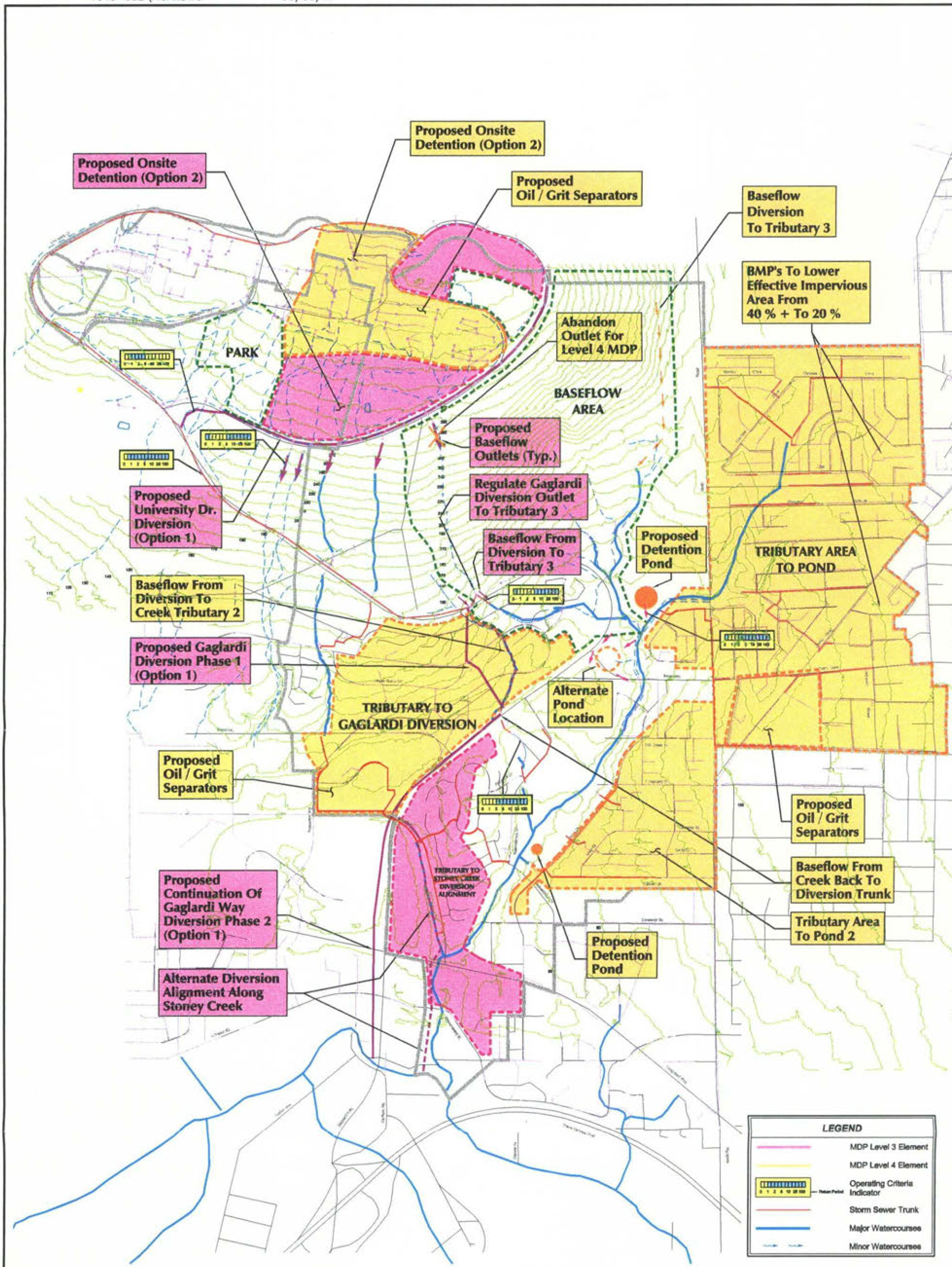
The Committee requested that the decision-making process for the study be documented so that others may understand how the elements of a master plan for integrated stormwater management were identified, evaluated and selected. Given that frame-of-reference, the purpose of this chapter has been to show how the 'six-step process' as illustrated on Figure 3-2 has been applied.

Figure 3-2 is a key graphic because it conceptualizes a proven approach to decision-making for complex issues. Of the six steps, five are applicable to the present study. The final step is for the municipal staffs to develop individual implementation plans that are consistent with direction provided by this study. Table 3-4 is therefore an important deliverable because it presents weighted decision criteria in matrix form.

APPENDIX C

PRELIMINARY GRAPHICS FOR ILLUSTRATING THE ELEMENTS OF A CONCEPT PLAN

1045-002\FIGA..DWG 98/08/17



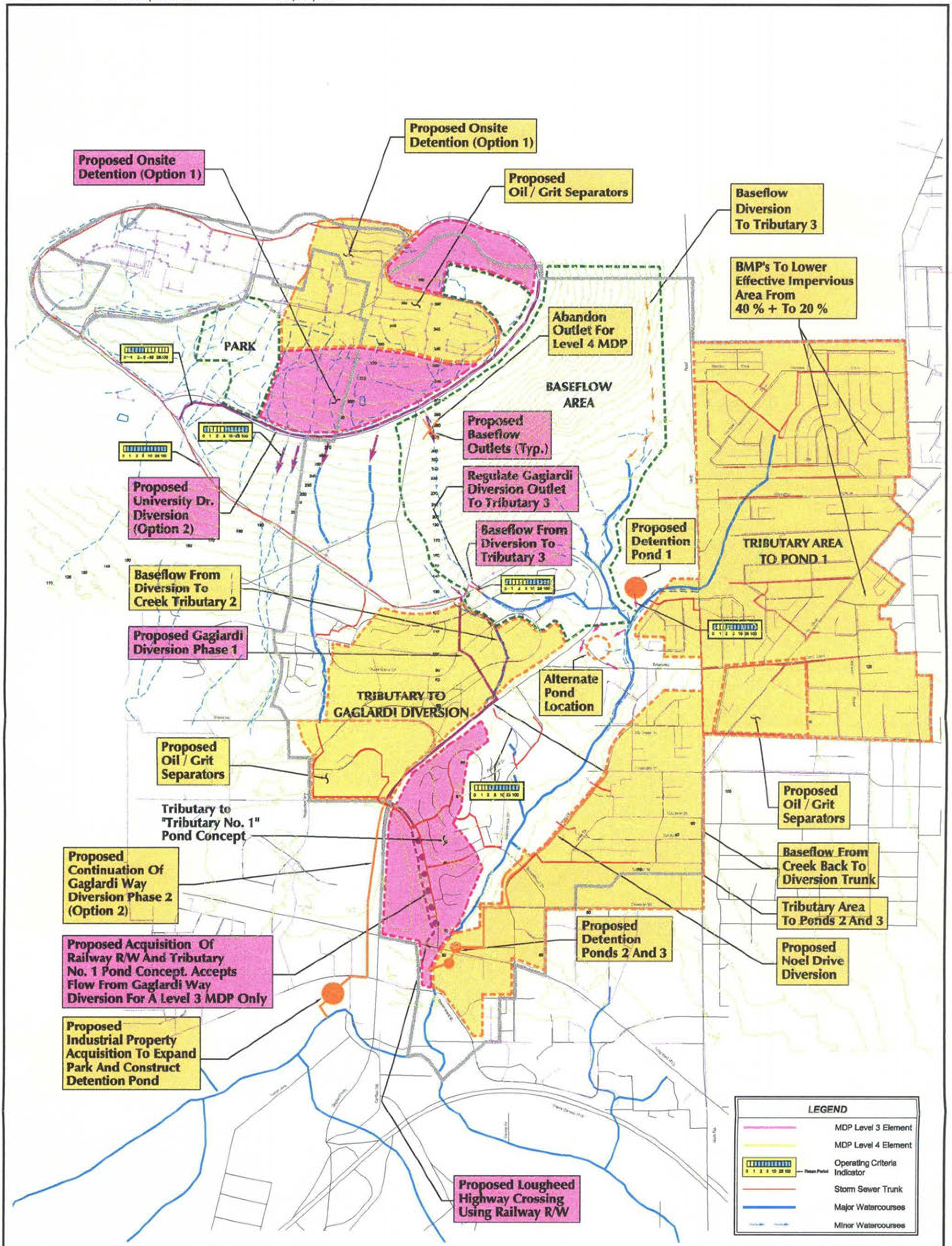
250 0 250
Scale In Metres

SELECTION OF ELEMENTS FOR THE ENVIRONMENTAL COMPONENT OF AN INTEGRATED MASTER DRAINAGE PLAN

(as presented at the August 12 th 1998 workshop)

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

FIGURE A



250 0 250
Scale In Metres

SELECTION OF ELEMENTS FOR THE ENVIRONMENTAL COMPONENT OF AN INTEGRATED MASTER DRAINAGE PLAN

(as presented at the September 11 th 1998 workshop)

KWL-CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

FIGURE B

APPENDIX D

DOCUMENTATION FOR WATERCOURSE INVESTIGATION PROGRAM

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
A	1	Main Branch	1	u/s		Confluence to Brunette River					x					No action
A	2	Main Branch	1	u/s		Brunette River at Stoney Creek Confluence					x					No action
A	3	Main Branch	1	u/s		Vehicle Bridge approx. 8 m upstream of Weir		x								No action
A	4	Main Branch	1	d/s		Vehicle Bridge approx. 8 m upstream of Weir		x								No action
A	5	Main Branch	1	u/s		Typical Cross-Section upstream of Vehicle Bridge					x					No action
A	6	Main Branch	1	u/s		Left bank erosion Length = 26 m	x									No action
A	7	Main Branch	1	u/s	Yes	Debris Jam				x						Remove debris jam
A	8	Main Branch	1	u/s		Typical Cross-section upstream of debris jam					x					No action
A	9	Main Branch	1	u/s	Yes	Railway - culvert outlet		x								Upgrade
A	10	Main Branch	1	d/s		Railway - culvert outlet		x								Upgrade
A	11	Main Branch	1	d/s		Railway - culvert outlet		x								Upgrade
A	12	Main Branch	1	u/s		Railway - culvert upstream channel					x					Upgrade
A	13	Main Branch	1	d/s		Railway - culvert inlet		x								Upgrade
A	14	Main Branch	1	u/s		Railway Bridge -immediately south of Gov.'t Road		x								No action
A	15	Main Branch	1	u/s		Railway Bridge -immediately south of Gov.'t Road		x								No action
A	16	Main Branch	1	u/s		Government Road culvert outlet		x								Upgrade
A	17	Main Branch	1	d/s		Government Road culvert inlet		x								Upgrade
A	18	Main Branch	2	u/s		Government Road upstream channel					x					No action
A	19	Main Branch	2	d/s		Fish Habitat Enhancement - approx. 20 m u/s of Gov.'t Road			x							No action
A	20	Main Branch	2	d/s		Fish Habitat Enhancement - approx. 20 m u/s of Gov.'t Road - left bank behind enhancement work - building near top of bank			x				x			No action
A	21	Main Branch	2	u/s		Typical channel d/s of Lougheed Hwy.					x					No action
A	22	Main Branch	2	u/s		Lougheed Hwy culvert outlet		x								Upgrade
A	23	Main Branch	2	d/s		Lougheed Hwy culvert inlet		x								Upgrade
A	24	Main Branch	3	u/s		Sanitary Sewer Crossing Trib. 1 u/s of Lougheed Hwy						x				Provide scour protection
B	1	Main Branch	3	u/s		Confluence Trib. 1 and Main Branch					x					No action
B	2	Main Branch	3	d/s	Yes	Rip Rap Erosion Protection - left bank downstream of outfall	x									No action
B	3	Main Branch	3			Tributary along right bank ??					x					No action
B	4	Main Branch	3	u/s		Typical channel btwn Lougheed Hwy and Ravine footbridge					x					No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
B	5	Main Branch	3	u/s		Typical floodplain between Lougheed Hwy and Beaverbrook Dr.					x					No action
B	6	Main Branch	3	u/s		Ravine Footbridge		x								No action
B	7	Main Branch	3	d/s		Building near top of ravine bank							x			No action
B	8	Main Branch	3	u/s		Erosion Protection Works - Right Bank - 18 m length - sewer alignment noted along same bank house located at top of ravine bank within same area. Would not want creek to enlarge in this area. 100 m upstream of footbridge	x					x	x			Protect toe of concrete wall.
B	9	Main Branch	3			House near top of ravine bank - across from photo no. 8 adjacent property similarly close to ravine edge							x			No action
B	10	Main Branch	3	u/s		Typical channel near house encroachment (photo no 8 and 9) channel 5 m width with rock bottom							x			No action
B	11	Main Branch	3	d/s		concrete weir	x	x								No action
no photo		Main Branch	3			concrete pad across channel approx. 25 m d/s of Beaverbrook Dr.	x	x				x?				No action
B	12	Main Branch	3	u/s		Beaverbrook Dr Bridge		x								No action
B	13	Main Branch	3	d/s		Beaverbrook Dr Bridge		x								No action
B	14	Main Branch	3			House at edge of creek adjacent and u/s of house in photo no. 9							x			No action
B	15	Main Branch	3			same photo as photo 14							x			No action
B	16	Main Branch	3	d/s		Typical floodplain d/s of Beaverbrook Dr.					x					No action
B	17	Main Branch	4	u/s		Typical floodplain u/s of Beaverbrook Dr.					x					No action
B	18	Main Branch	4	d/s		Erosion site, left bank approx. 20 m upstream of Beaverbrook Dr.. Immediately upstream of storm outfall. See Inv. Sht 2	x									Gully formation associated with storm outfall. Banks should be stabilized.
B	19	Main Branch	4	d/s		Channel downstream of log jam approx. 150 m upstream of Beaverbrook Dr.				x	x					No action
B	20	Main Branch	4	u/s		Debris jam approx. 150 m u/s of Beaverbrook Dr. within park - right bank eroding u/s of log jam	x			x						No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhancement	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
B	21	Main Branch	4	u/s		Park foot bridge washed out at confluence of Tributary 2 with main branch	x	x		x						If foot bridge is not going to be replaced, material from old bridge should be removed and banks stabilized.
B	22	Main Branch / Tributary 2	4	u/s	Yes?	Park foot bridge		x								No action
B	23	Main Branch	4	d/s		Typical channel through Park	x				x					No action
B	24	Main Branch	4		Yes	Debris jam - large build up of bedload behind felled tree - new channel formed to left of tree - within park area - right bank				x						No action
B	25	Main Branch	4		Yes	Debris jam - large build up of bedload behind felled tree - new channel formed to left of tree - within park area - left bank				x						No action
B	26	Main Branch	4	d/s		Beaverbrook Dr school yard drainage into Main Branch - erosion - possibly contributing to sediment loading within Main Branch	x									Provide surface erosion stabilization
C	1	Main Branch	4	u/s	Yes	Park foot bridge		x								No action
C	2	Main Branch	5	d/s		Typical channel downstream of footbridge in photo C1					x					No action
C	3	Main Branch	5	d/s	Yes	Erosion site, right bank - steep channel grades - erosion protection vegetation matting placed in previous years to protect embankment near trail on left bank within same area	x									Reach requires contined works to mitigate existing erosion
C	4	Main Branch	5	d/s		Typical channel downstream of concrete weirs (d/s of Stoney Creek Pl.					x					No action
C	5	Main Branch	5	u/s		Concrete weirs #1 d/s of Stoney Creek Pl	x	x								Erosion mitigation required around weirs
C	6	Main Branch	5	u/s	Yes	Concrete weirs #2 d/s of Stoney Creek Pl approx. 32 m u/s of weir #1	x	x								Erosion mitigation required around weirs
C	7	Main Branch	5	u/s		Typical channel d/s of weir #2										No action
C	8	Main Branch	5	u/s		Concrete weir #3 - seepage noted along right bank eroding soils support of weir - weir has partially failed in eroded area - weir located approx. 80 m d/s of Stoney Creek Pl bridge crossing.	x	x								Erosion mitigation required around weirs
C	9	Main Branch	5	u/s		Stoney Creek Pl. bridge - creek to left of path.		x								No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhancement	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
C	10	Main Branch	5	d/s		Stoney Creek Pl. bridge - creek underneath bridge - minor erosion of banks beneath bridge	x	x								Stabilize bank with vegetative cover
C	11	Main Branch	5	d/s	Yes	House near top of creek right bank - u/s of Stoney Creek Pl. bridge							x			No action
C	12	Main Branch	5	u/s		Broadway bridge		x								No action
C	13	Main Branch	6	u/s	Yes?	Storm sewer outfall Rathburn Dr. - approx. 50 m upstream of Broadway bridge - oranage slim on substrate		x						x		No action
C	14	Main Branch	6	d/s		Typical channel upstream of Broadway bridge					x					No action
C	15	Main Branch	6	d/s	Yes?	Erosion protection works , left bank - protects path adjacent creek - 11 m long, 3 m high, 450 - 850 mm dia. - property fence approx 8 m from top of bank	x									No action
C	16	Main Branch	6	d/s	Yes	Tributary 3 confluence with main branch					x					No action
C	17	Main Branch	6	u/s		Typical channel upstream of erosion works in photo 16					x					No action
C	18	Main Branch	6	u/s	Yes	Storm sewer outfall- Jefferson Ave. 1200mm dia		x								No action
C	19	Main Branch	6	d/s		Storm sewer outfall - Jefferson Ave. - wingwall within channel alignment	x	x								Restore wall support and protect against erosion.
C	20	Main Branch	6	d/s		Pathway adjacent left bank near Jefferson Ave. outfall							x			No action
C	21	Main Branch	6	u/s		Typical channel - note concrete wall from upstream weir/ erosion protection	x				x					Remove concrete wall from watercourse
C	22	Main Branch	6	u/s	Yes	Concrete weirs (2) - approx. 70 m d/s of North Rd		x								No action
C	23	Main Branch	6			North Rd culvert outlet - no photo		x								No action
D	1	Main Branch	6	d/s		North Rd culvert inlet - rip rap stone from upstream built up around culvert inlet		x								Remove rock build up at inlet
D	2	Main Branch	7	u/s		Rip rap lined channel upstream of North Road culvert	x				x					No action
D	3	Main Branch	7	u/s	Yes	Concrete lined channel right bank - approx 20 m u/s of North Rd - 16 m length 1.5 m high - tributary noted 16m u/s of GPS point along left bank, 1m width constant flow	x						x		x	No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
D	4	Main Branch	7	d/s		Same property as photo 3 - taken at upstream property line										No action
D	No phot	Main Branch	7			Side channel, left bank - 40 m u/s of photo D4 property line - 1.8 m wide, steep channel grade, moss covered boulders, constant trickle									x	No action
D	5	Main Branch	7	u/s		Typical channel u/s of North Rd.					x					No action
D	6	Main Branch	7	u/s		Typical channel u/s of North Rd.					x					No action
D	7	Main Branch	7	u/s		GVSS&DD manhole on left bank - 300mm dia. Pvc pipe outlet conc. Drop (in channel?) = 0.8 m - d/s limit of murky water		x				x		x		No action
D	No phot	Main Branch	7			murky water source from 50 mm pvc from private property along right bank approx. 20m u/s of GVSS&DD manhole.								x		Contact property owner regarding source of water discharge.
D	8	Main Branch	7	u/s		Erosion protection, right bank - concrete block retaining wall 36 m length 2 m high - u/s limit of protection approx. 12 m d/s of Chapman Rd.	x									No action
D	9	Main Branch	7	u/s		Chapman Rd. culvert outlet - 1300 mm dia. Orange slim at outlet		x						x		No action
D	10	Main Branch	7	u/s		Typical floodplain d/s of Chapman Road					x					No action
D	11	Main Branch	7	u/s		Typical floodplain u/s of Chapman Rd.					x					No action
D	12	Main Branch	8	d/s		Chapman Rd. culvert inlet - 1300 mm dia.		x								No action
D	13	Main Branch	8	d/s		Chapman Rd. culvert inlet - 1300 mm dia.		x								No action
D	14	Main Branch	8	d/s		Driveway bridge -approx. 50 m upstream of Chapman Rd.		x								No action
D	15	Main Branch	8	u/s	Yes	Concrete weir		x								No action
D	16	Main Branch	8	u/s		Typical channel u/s of Chapman Rd.					x					No action
D	17	Main Branch	8	u/s		Ailsa Ave. culvert outlet		x								Refer to culvert assessment for upgrades
D	18	Main Branch	8	d/s		Typical channel d/s of Ailsa Ave.					x					No action
D	19	Main Branch	8	d/s		Ailsa Ave. culvert inlet		x								Refer to culvert assessment for upgrades
D	20	Main Branch	8	u/s		Channel u/s of Ailsa Ave culvert					x					No action
D	21	Main Branch	8	u/s		Storm sewer outfalls at upper limit of Stoney Creek Main Branch		x								No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
D	22	Main Branch	8	u/s		Storm sewer outfalls at upper limit of Stoney Creek Main Branch		x								No action
D	23	Main Branch	8	u/s		Storm sewer outfalls at upper limit of Stoney Creek Main Branch		x								No action
D	24	Main Branch	8	d/s		Channel downstream of storm sewers outfalls at main branch upper limit					x					No action
D	25	Tributary 1	M.B. to Gaglardi Way	u/s		Sewer crossing 10 m u/s of main branch confluence - low flows beneath pipe through partially collapsed pipe place below sewer pipe - water smells and rocks covered in orange or white slim upstream of pipe crossing						x		x		Provide channel scour remediation around pipe.
E	1	Tributary 1	M.B. to Gaglardi Way	u/s		Typical channel u/s of pipe crossing in photo D25					x					No action
E	2	Tributary 1	M.B. to Gaglardi Way	u/s		Storm outfall pipe - 600 mm dia. left bank		x								No action
E	3	Tributary 1	M.B. to Gaglardi Way	d/s		Typical channel d/s of East Lake Rd. outfall					x			x		No action
E	4	Tributary 1	M.B. to Gaglardi Way	u/s		Storm sewer outfall - East Lake Rd. Limit of		x								No action
E	5	Tributary 1	M.B. to Gaglardi Way	d/s		Typical channel d/s of East Lake Rd. outfall					x					No action
E	6	Tributary 1	u/s of Broadwa y R.O.W.	u/s	Yes?	Storm sewer inlet to piped section of Tributary 1 - u/s channel		x			x					No action
E	7	Tributary 1	u/s of Broadwa y R.O.W.	d/s		Storm sewer inlet to piped section of Tributary 1 - main inlet		x								No action
E	8	Tributary 1	u/s of Broadwa y R.O.W.	d/s		Storm sewer inlet to piped section of Tributary 1 - emergency flow inlet		x								No action
E	9	Tributary 1	u/s of Broadwa y R.O.W.	u/s	Yes	Storm sewer outfall - 450 mm dia.		x								No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
E	10	Tributary 1	u/s of Broadway R.O.W.	u/s		Debris jam and footbridge		x		x						Remove debris jam
E	11	Tributary 1	u/s of Broadway R.O.W.	d/s		Townhomes within 15 m of top of ravine bank - vegetation cut to edge of right creek/ravine on inside bend of creek							x			No action
E	12	Tributary 1	u/s of Broadway R.O.W.	u/s	Yes	Typical channel d/s of Forest Grove Drive					x					No action
E	13	Tributary 1	u/s of Broadway R.O.W.	u/s	Yes	Forest Grove culvert outlet		x								Refer to culvert assessment for upgrades
E	14	Tributary 1	u/s of Broadway R.O.W.	d/s		Forest Grove culvert inlet		x								Refer to culvert assessment for upgrades
E	15	Tributary 1	u/s of Broadway R.O.W.	u/s		Channel u/s of Forest Grove - adjacent school					x					No action
E	16	Tributary 1	u/s of Broadway R.O.W.	u/s		Storm sewer inlet to piped section of Tributary 1 - u/s channel		x								No action
E	17	Tributary 1	u/s of Broadway R.O.W.	u/s	Yes	Foot path culvert within pipeline R.O.W. - 800mm dia. PVC, 4 m length		x				x				No action
E	18	Tributary 1	u/s of Broadway R.O.W.	d/s		Foot path culvert within pipeline R.O.W. - 800mm dia. PVC, 4 m length		x								No action
E	19	Tributary 1	u/s of Broadway R.O.W.	d/s	Yes	Private townhouse road culvert - outlet - 1 m dia. 16 m length		x								Refer to culvert assessment for upgrades
E	20	Tributary 1	u/s of Broadway R.O.W.	d/s		Private townhouse road culvert - inlet - rock build up noted at inlet		x								Refer to culvert assessment for upgrades

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhancement	Debris Jam	Typical Channel	Pipeline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
E	21	Tributary 1	u/s of Broadway R.O.W.	d/s	Yes	Rip rap stone lining of left bank - outside bend in creek - 250-300mm dia. 0.5 m high 24 m length	x									No action
E	22	Tributary 1	u/s of Broadway R.O.W.	u/s		Typical channel downstream of Gaglardi Way					x					No action
E	23	Tributary 1	u/s of Broadway R.O.W.	u/s	Yes	Gaglardi Way culvert outlet - 950 mm dia cmp - scour pool at outlet	x	x								Energy dissipator required at outlet
E	24	Tributary 1	u/s of Broadway R.O.W.			Gaglardi Way culvert inlet - 950 mm dia cmp - scour pool at outlet		x								Energy dissipator required at outlet
E	25	Tributary 2	d/s of Beaverbrook Dr.	d/s	Yes	Tributary 2 confluence with Stoney Creek - failed bridge associated with erosion of main branch right bank	x									Stabilize banks and replace foot bridge.
F	1	Main Branch	4	d/s		Channel d/s of Tributary 2 confluence					x					No action
F	no phot	Tributary 2	d/s of Beaverbrook Dr.			Debris jam d/s of wood foot bridge substrate build up behind felled tree - low flows diverted around left bank				x						No action
F	2	Tributary 2	d/s of Beaverbrook Dr.	u/s		Foot bridge - erosion of concrete cylinder wall noted	x	x								Remove concrete debris in channel and stabilize channel banks.
F	3	Tributary 2	d/s of Beaverbrook Dr.	u/s		Erosion protection work , right bank - failed -	x									Remove concrete debris in channel and stabilize channel banks.
F	4	Tributary 2	d/s of Beaverbrook Dr.	u/s	Yes	Foot bridge from school yard		x								No action
F	5	Tributary 2	d/s of Beaverbrook Dr.	u/s		Beaverbrook Dr. culvert outlet		x								No action
F	6	Tributary 2	u/s of Beaverbrook Dr.	u/s		Channel u/s of Beaverbrook Dr. creek piped section		x			x					No action
F	7	Tributary 2	d/s of Beaverbrook Dr.	d/s		Beaverbrook Dr. creek piped section		x								No action
F	8	Tributary 2	u/s of Beaverbrook Dr.	u/s	Yes	Arch culvert within Beaverbrook Dr. Townhouse complex		x								No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
F	9	Tributary 2	u/s of Beaverbrook Dr.	u/s		Foot bridge upstream of arch culvert within Beaverbrook Dr. Townhouse complex		x								No action
F	10	Tributary 2	btwn Gaglardi Way	u/s		Typical channel upstream of Forest Grove Dr.					x					No action
F	11	Tributary 2	btwn Gaglardi Way	u/s	Yes	Footbridge		x								No action
F	12	Tributary 2	btwn Gaglardi Way	u/s		Forest Grove Culvert north - outlet		x								No action
F	13	Tributary 2	btwn Gaglardi Way	d/s		Channel d/s of Forest Grove culvert north					x					No action
F	14	Tributary 2	btwn Gaglardi Way	d/s		Forest Grove culvert north - inlet		x								No action
F	15	Tributary 2	btwn Gaglardi Way	u/s		Right bank erosion - approx. 20 m u/s of footbridge	x									Remove concrete debris in channel and stabilize channel banks
F	16	Tributary 2	btwn Gaglardi Way	d/s		Channel d/s of Ash Grove Cres. Culvert		x			x					No action
F	17	Tributary 2	btwn Gaglardi Way	u/s		Ash Grove Cres. Culvert - outlet - stones set in concrete pad serve as energy disipator		x								No action
F	18	Tributary 2	btwn Gaglardi Way	d/s	Yes	Footbridge		x								No action
F	19	Tributary 2	btwn Gaglardi Way	u/s		Right bank - townhomes at erosion site near top of bank							x			Erosion remediation required
F	20	Tributary 2	btwn Gaglardi Way	d/s		Ash Grove Cres. culvert - inlet		x								Refer to culvert assessment
F	21	Tributary 2	btwn Gaglardi Way	u/s	Yes	Gaglardi Way culvert - outlet - within pipeline right of way		x								Refer to culvert assessment
F	22	Tributary 2	btwn Gaglardi Way	d/s	Yes	Gaglardi Way culvert - inlet - 700 mm dia.		x								Refer to culvert assessment
F	23	Tributary 2	btwn Gaglardi Way	u/s		Forest Grove culvert south - outlet		x								Refer to culvert assessment

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
F	24	Tributary 2	btwn Gaglardi Way	d/s		Channel downstream of Forest Grove culvert					x					No action
F	25	Tributary 2	btwn Gaglardi Way	d/s		Forest Grove culvert south - inlet		x								Refer to culvert assessment
G	1	Tributary 2	btwn Gaglardi Way	u/s	Yes	Footpath culvert inlet - partially collapsed metal pipe - approx. 20 m upstream of south Gaglardi Way culvert		x								No action
G	2	Tributary 2	btwn Gaglardi Way	d/s		Gaglardi Way south culvert - inlet		x								No action
G	3	Tributary 1	u/s of Gaglardi Way		Yes	Culvert 1 along access road - inlet 600 mm		x								No action
G	4	Tributary 1	u/s of Gaglardi Way			Culvert 2 along access road - outlet		x								No action
G	5	Tributary 1	u/s of Gaglardi Way		Yes	Culvert 2 along access road - downstream channel					x					No action
G	6	Tributary 1	u/s of Gaglardi Way			Culvert 2 along access road - inlet 450 mm dia pipe		x								No action
G	7	Tributary 1	u/s of Gaglardi Way		Yes	Culvert 3 along access road - outlet - 450 mm dia - no flow		x								No action
G	8	Tributary 1	u/s of Gaglardi Way		Yes	Culvert 3 - inlet location		x								No action
G	9	Tributary 1	Universi ty Dr.			Culvert 4 - 600 mm dia outlet silts at outlet					x					No action
G	10	Tributary ??	Universi ty Dr.			Culvert 5 - outlet 700 mm dia cmp channel eroding d/s of concrete spill pad creating 0.3 m drop - channel and flows much larger than noted at water tank driveway entrance culverts. - differenct drainage system		x								Stabilize channel downstream of outlet
G	11	Tributary ??	Universi ty Dr.			Culvert 5 - downstream channel - 1.5 m wide, 1.5m to 0.5 m 1 m deep channel					x					No action
G	12	Tributary ??	Universi ty Dr.		Yes	Concrete Spillway 0.9m drop width =2.5 m u.s channel 1.3m rip rap stone 200 to 300 mm dia.		x								No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
G	13	Tributary ??	Pipeline R.O.W. north of Gaglardi Way		Yes	Pipe crossing d/s of concrete weir in photoG12		x								No action
G	14	Tributary ??	Pipeline R.O.W. north of Gaglardi Way			Pipe line R.O.W. north/adjacent Gaglardi Way - concrete weir in photo G13 is within gully						x				No action
G	15	Tributary??	Pipeline R.O.W. north of Gaglardi Way		Yes	Culvert - 300mm metal , 5m long - ditch dry		x								No action
G	16	Tributary ??	Pipeline R.O.W. north of Gaglardi Way		Yes	Culvert - 300mm dia, metal - collapsed - low flow		x								No action
G	17	Tributary ??	Universi ty Dr.	d/s		Channel d/s of 900mm cmp outfall										No action
G	18	Tributary ??	Universi ty Dr.	u/s	Yes	900mm dia storm outfall across from driveway to Discovery Park										No action
G	19	Tributary 3	Gaglardi Way		Yes	Water source to manhole adjacent Gaglardi Way near Ash Grove										No action
G	20	Tributary 3	Gaglardi Way			50mm dia hose within same location as water tap.										No action
G	21	Tributary ??	Pipeline R.O.W. north of Gaglardi Way	d/s	Yes	800mm dia metal culvert 8 m length - ditch is 1.5m width 5cm depth		x			x					No action
G	22	Tributary 3	Pipeline R.O.W. north of Gaglardi Way	u/s	Yes	metal pipe across channel - joints are not connected - forms a 0.9m drop at crossing - culvert inlet noted within same area on north side of path - outlet not located - constant flow within the 0.4m wide ditch - diagram of area included in field notes		x				x				No action
G	23	Tributary 3	Pipeline R.O.W. north of Gaglardi Way	d/s	Yes	Typical channel across pipeline R.O.W. 9 - 0.1 m wood steps within channel - old metal culvert buried within channel u/s of path - 1m width wetted perimeter						x				No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
G	24	Tributary 3	Gaglardi Way	u/s	Yes	Storm sewer outfall - 600mm dia concrete pipe - no base flow		x								No action
G	25	Tributary 3	Gaglardi Way	u/s	Yes	Gaglardi Way culvert crossing - outlet		x								No action
H	1	Tributary 3	Gaglardi Way	d/s		Gaglardi Way culvert crossing - inlet		x								No action
H	2	Tributary 3	Gaglardi Way	d/s	Yes	Gaglardi Way culvert - d/s channel					x					No action
H	3	Tributary 3	Branch 1	u/s	Yes	Gaglardi Way east ditch footpath culvert - north of Tributary 3 main channel - 1m dis 2 m length - outlet		x								No action
H	4	Tributary 3	Gaglardi Way ditch	u/s		Gaglardi Way east ditch d/s channel from footpath culvert - width = 1.3m 450 mm dia riprap, height = 1.5 m Road height = 4m					x					No action
H	5	Tributary 3	Gaglardi Way ditch	d/s		Gaglardi Way east ditch footpath culvert - north of Tributary 3 main channel - inlet		x								No action
H	6	Tributary 3	btwn Gaglardi Way two crossing s			Debris jam 75 m u/s of Gaglardi Way culvert - not well anchored - should be removed				x						Remove debris jam
H	7	Tributary 3	btwn Gaglardi Way two crossing s	u/s	Yes	Foot bridge d/s of Hydro R.O.W.		x								No action
H	8	Tributary 3	btwn Gaglardi Way two crossing s	u/s		Typical channel between the hydro R.O.W. and south Gaglardi Way crossing					x					No action
H	9	Tributary 3	btwn Gaglardi Way two crossing s	u/s		Typical channel through Hydro R.O.W.					x					No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhancement	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
H	10	Tributary 3	btwn Gaglardi Way two crossings			300mm dia PVC outfall - left bank d/s of Aspen Grove - orange slim on rocks at outlet		x								No action
H	11	Tributary 3	btwn Gaglardi Way two crossings	u/s		Aspen Grove culvert - outlet		x								Refer to culvert assessment
H	12	Tributary 3	btwn Gaglardi Way two crossings			Storm Sewer outfall - immediately d/s of Aspen Grove crossing - left bank		x								No action
H	13	Tributary 3	btwn Gaglardi Way two crossings			Aspen Grove culvert - inlet		x								Refer to culvert assessment
H	14	Tributary 3	btwn Gaglardi Way two crossings	u/s		left bank side channel 300 mm dia PVC pipe outlet and rock barrier									x	No action
H	15	Tributary 3	btwn Gaglardi Way two crossings	u/s	Yes	Footbridge upstream of Aspen Grove - steep meandering channel with rip rap lining along the length	x	x								No action
H	16	Tributary 3	btwn Gaglardi Way two crossings	d/s		right bank -townhomes constructed within 2 m of channel edge - located 15 m u/s of footbridge (photo H15)							x			No action

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhance ment	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
H	17	Tributary 3	btwn Gaglardi Way two crossings	u/s		left bank - townhomes less than 2 m from creek bank							x			No action
H	18	Tributary 3	btwn Gaglardi Way two crossings	u/s	Yes	Mooreside Pl driveway bridge		x								No action
H	19	Tributary 3	btwn Gaglardi Way two crossings	u/s	Yes	Ash Grove north culvert - outlet		x								Refer to culvert assessment
H	20	Tributary 3	btwn Gaglardi Way two crossings	u/s		Ash Grove north culvert - inlet		x								Refer to culvert assessment
H	21	Tributary 3	btwn Gaglardi Way two crossings	u/s		Ash Grove north culvert - u/s channel							x			No action
H	22	Tributary 3	btwn Gaglardi Way two crossings	u/s		Right bank erosion - d/s of Gaglardi Way culvert same location as photo H24	x									Provide energy disipator at culvert outlet and stabilize bank
H	23	Tributary 3	btwn Gaglardi Way two crossings		Yes	Gaglardi Way culvert - outlet										Provide energy disipator at culvert outlet and stabilize bank

Photograph Inventory of Field Investigations

Roll No.	Photo No.	Watercourse	Reach	Photo taken U/S or D/S	GPS	Description	Erosion/ Erosion Protection Works	Structure	Enhancement	Debris Jam	Typical Channel	Pipelline Creek Crossing	Development Encroach - ment	Water Quality	Side channel noted	Recommendations
H	24	Tributary 3	btwn Gaglardi Way two crossings			Right bank erosion - d/s of Gaglardi Way culvert - 20m 12 m height - no development adjacent top of bank	x									Provide energy dissipator at culvert outlet and stabilize bank.
I	1	Tributary 3	btwn Gaglardi Way two crossings	u/s	Yes	Side channel outfall u/s of photo H14 - 300 mm dia - orange slim noted on rocks		x							x	No action
I	2	Tributary 3	Branch 1			Fish habitat enhancements			x							No action
I	3	Tributary 3	Branch 1	u/s	Yes	Typical channel u/s of Gaglardi Way through Hydro R.O.W.					x					No action
I	4	Tributary 2	u/s of Beaverbrook Dr.	u/s		Arch culvert -inlet - same culvert as photo F8										No action
I	5	Tributary 2	u/s of Beaverbrook Dr.			Gaglardi Way pipe creek outfall - 1050 mm										No action

APPENDIX E

DOCUMENTATION FOR RAINFALL-RUNOFF MODELLING

100 YEAR STORM EVENTS (Unrestricted Flow)

Pipe No.	Peak Flows (m^3/s)				
	1 hr	2 hr	6 hr	12 hr	24 hr
489	9.05	4.26	3.57	2.64	1.94
491	8.81	3.97	3.57	2.64	1.94
493	8.75	3.97	3.57	2.64	1.94
495	8.66	3.81	3.56	2.64	1.94
497	8.54	3.76	3.56	2.64	1.94
499	8.51	3.66	3.56	2.63	1.94
501	8.36	3.63	3.56	2.63	1.94
503	8.37	3.54	3.56	2.63	1.94
505	8.25	3.49	3.55	2.63	1.94
507	8.23	3.42	3.55	2.63	1.94
509	8.12	3.38	3.55	2.63	1.94
511	8.10	3.30	3.55	2.63	1.94
513	8.01	3.28	3.55	2.63	1.94
516	7.99	3.22	3.55	2.63	1.94
518	7.92	3.21	3.55	2.63	1.94
520	9.43	3.69	5.07	3.81	2.84
1001	1.42	0.58	0.66	0.50	0.37
1002	1.31	0.56	0.59	0.45	0.33
1003	1.32	0.56	0.59	0.45	0.33
1004	1.33	0.58	0.59	0.45	0.33
1005	1.35	0.58	0.59	0.45	0.33
1006	1.36	0.60	0.60	0.45	0.33
1007	1.38	0.61	0.60	0.45	0.33
1008	1.40	0.63	0.60	0.45	0.33
1009	1.42	0.64	0.60	0.45	0.33
1010	1.45	0.69	0.60	0.45	0.33
1011	0.17	0.07	0.07	0.05	0.04
1012	0.17	0.08	0.07	0.05	0.04
1101	0.72	0.29	0.35	0.27	0.20
1102	0.73	0.30	0.35	0.27	0.20
1103	0.74	0.31	0.35	0.27	0.20
1104	0.75	0.32	0.36	0.27	0.20
1105	0.78	0.35	0.36	0.27	0.20
1200	-	-	-	-	-
-	1.58	0.60	0.98	0.79	0.63
-	1.58	0.60	0.98	0.79	0.63
1201	3.18	1.24	1.96	1.59	1.25
1202	1.73	0.59	1.34	1.13	0.91
1203	1.76	0.62	1.35	1.13	0.91
1204	1.50	0.70	0.62	0.46	0.35
1205	1.53	0.72	0.62	0.46	0.35
1206	1.56	0.76	0.63	0.46	0.35
1301	1.28	0.54	0.58	0.44	0.33
1302	0.69	0.29	0.32	0.24	0.18
1303	0.70	0.29	0.32	0.24	0.18
1304	0.35	0.15	0.16	0.12	0.09
1305	0.37	0.17	0.16	0.12	0.09
1401	1.69	0.71	0.79	0.60	0.45
1402	1.71	0.72	0.79	0.60	0.45
1403	1.75	0.74	0.79	0.60	0.45
1404	1.76	0.76	0.79	0.60	0.45
1405	1.78	0.78	0.79	0.60	0.45

100 YEAR STORM EVENTS (Unrestricted Flow)

Pipe No.	Peak Flows (m^3/s)				
	1 hr	2 hr	6 hr	12 hr	24 hr
1406	1.80	0.80	0.80	0.60	0.45
1407	1.82	0.81	0.80	0.60	0.45
1408	1.87	0.87	0.80	0.60	0.45
1501	4.86	2.35	4.03	3.42	2.65
1502	4.87	2.35	4.03	3.42	2.65
1503	4.87	2.35	4.03	3.42	2.65
1504	3.27	1.75	3.27	2.86	2.23
1505	3.27	1.76	3.27	2.86	2.23
1506	5.15	1.76	3.61	2.87	2.23
1507	5.15	1.77	3.61	2.87	2.24
1508	4.86	1.67	3.32	2.65	2.06
1509	4.87	1.68	3.32	2.65	2.07
1510	4.87	1.69	3.32	2.65	2.07
1601	1.60	0.66	0.76	0.57	0.42
1602	1.61	0.67	0.76	0.57	0.42
1603	1.61	0.67	0.76	0.57	0.42
1604	1.61	0.67	0.76	0.57	0.42
1605	1.67	0.69	0.76	0.57	0.42
1606	1.67	0.70	0.76	0.57	0.42
1607	1.70	0.71	0.76	0.57	0.42
1608	1.70	0.72	0.76	0.57	0.42
1609	1.74	0.74	0.76	0.57	0.42
1610	1.74	0.75	0.76	0.57	0.42
1611	1.78	0.79	0.76	0.57	0.42
1701	2.77	1.11	1.40	1.08	0.82
1702	2.77	1.12	1.40	1.08	0.83
1703	2.81	1.13	1.41	1.08	0.83
1704	2.81	1.15	1.41	1.08	0.83
1705	2.85	1.17	1.41	1.08	0.83
1706	2.86	1.18	1.41	1.09	0.83
1707	2.88	1.21	1.41	1.09	0.83
1708	2.91	1.24	1.41	1.09	0.83
1709	2.91	1.22	1.41	1.09	0.83
1710	2.98	1.28	1.42	1.09	0.83
1711	2.98	1.28	1.42	1.09	0.83
1712	3.07	1.38	1.42	1.09	0.83
1801	3.71	1.26	2.48	1.98	1.54
1802	3.70	1.26	2.48	1.98	1.54
1803	3.06	1.03	2.16	1.74	1.36
1804	2.50	0.85	1.71	1.39	1.08
1805	2.50	0.85	1.71	1.39	1.08
1901	0.69	0.29	0.31	0.24	0.18
1902	0.71	0.31	0.31	0.24	0.18
1903	0.72	0.32	0.31	0.24	0.18
1904	0.72	0.33	0.32	0.24	0.18
1905	0.74	0.35	0.32	0.24	0.18
2001	1.22	0.58	0.51	0.38	0.28
2002	1.16	0.54	0.51	0.38	0.28
2100	0.98	0.42	0.44	0.33	0.25
2101	0.99	0.45	0.44	0.33	0.25
2102	1.01	0.45	0.44	0.33	0.25
2103	1.03	0.48	0.44	0.34	0.25

100 YEAR STORM EVENTS (Unrestricted Flow)

Pipe No.	Peak Flows (m^3/s)				
	1 hr	2 hr	6 hr	12 hr	24 hr
2201	0.00	0.00	0.00	0.00	0.00
2202	0.00	0.00	0.00	0.00	0.00
2203	0.00	0.00	0.00	0.00	0.00
2204	0.00	0.00	0.00	0.00	0.00
3001	1.68	0.75	0.72	0.54	0.40
3002	1.70	0.78	0.72	0.54	0.40
3003	1.74	0.83	0.72	0.54	0.40
4001	0.51	0.22	0.23	0.18	0.13
4002	0.52	0.22	0.23	0.18	0.13
4003	0.53	0.25	0.23	0.18	0.13
5001	1.36	0.61	0.57	0.42	0.31
5002	1.38	0.64	0.57	0.42	0.31
5003	1.42	0.69	0.57	0.42	0.31
6001	0.85	0.40	0.35	0.26	0.19
7001	4.89	1.82	2.42	1.84	1.38
7002	4.91	1.84	2.42	1.84	1.38
7003	4.95	1.86	2.42	1.84	1.38
7004	4.97	1.88	2.42	1.84	1.38
7005	4.99	1.88	2.43	1.84	1.38
7006	4.97	1.88	2.43	1.84	1.38
7007	4.04	1.64	1.87	1.42	1.06
7008	4.08	1.65	1.87	1.42	1.06
7009	1.69	0.70	0.79	0.60	0.45
7010	1.72	0.73	0.79	0.60	0.45
7011	1.77	0.76	0.80	0.61	0.45
7013	2.19	0.98	0.95	0.72	0.53
7014	1.50	0.67	0.65	0.48	0.36
7015	0.72	0.33	0.32	0.24	0.18
7016	0.31	0.17	0.11	0.08	0.06
7017	0.83	0.39	0.33	0.24	0.18
8001	2.41	1.01	1.15	0.87	0.66
8002	2.45	1.04	1.15	0.88	0.66
8003	0.88	0.37	0.42	0.32	0.24
8004	0.91	0.39	0.42	0.32	0.24
8005	0.93	0.41	0.42	0.32	0.24
8006	0.38	0.17	0.17	0.13	0.10
8007	0.39	0.18	0.17	0.13	0.10
8008	1.65	0.75	0.74	0.56	0.42
8010	1.84	0.71	0.93	0.71	0.53
8011	1.56	0.59	0.79	0.60	0.45
8012	0.96	0.40	0.45	0.34	0.26
8013	0.98	0.41	0.45	0.34	0.26
8014	0.98	0.42	0.45	0.34	0.26
8015	1.00	0.43	0.45	0.35	0.26
8016	1.00	0.44	0.45	0.35	0.26
8017	1.01	0.45	0.46	0.35	0.26
8018	0.84	0.39	0.37	0.28	0.21
9001	1.25	0.53	0.59	0.45	0.34
9002	1.30	0.57	0.59	0.45	0.34
10001	2.79	1.17	1.33	1.02	0.77
10002	2.81	1.17	1.33	1.02	0.77
10003	2.86	1.24	1.34	1.02	0.77

100 YEAR STORM EVENTS (Unrestricted Flow)

Pipe No.	Peak Flows (m^3/s)				
	1 hr	2 hr	6 hr	12 hr	24 hr
10004	2.88	1.24	1.34	1.02	0.77
10005	2.96	1.33	1.34	1.02	0.77
20001	2.52	0.86	1.72	1.39	1.08
20002	2.52	0.86	1.72	1.39	1.08
R1	40.69	14.42	32.80	27.42	21.79
R10-1	3.63	1.24	2.46	1.97	1.53
R10-2	2.51	0.85	1.72	1.39	1.08
R10-3	2.15	0.75	1.46	1.19	0.93
R10-4	2.02	0.74	1.31	1.06	0.83
R10-5	1.04	0.33	0.80	0.67	0.54
R10-6	0.85	0.28	0.62	0.52	0.41
R11-1	16.25	5.46	11.23	8.95	6.95
R11-2	11.05	4.00	6.82	5.25	3.97
R11-3	10.36	3.86	6.12	4.69	3.55
R11-4	10.44	3.88	6.13	4.69	3.55
R11-5	10.60	3.98	6.16	4.70	3.55
R12	5.00	1.65	3.75	3.13	2.50
R2	41.28	14.56	32.94	27.48	21.81
R3	34.15	11.62	26.16	21.71	17.11
R4-1	33.64	11.45	25.10	20.67	16.22
R4-2	30.46	10.45	22.29	18.22	14.29
R5	30.16	10.40	21.72	17.68	13.79
R6-1	30.04	10.34	20.58	16.50	12.80
R6-2	15.04	5.47	9.62	7.63	5.86
R6-3	11.03	4.04	7.29	5.81	4.48
R7	7.66	2.84	4.97	3.97	3.08
R8-1	7.05	2.73	4.26	3.38	2.61
R8-2	4.00	1.50	2.53	2.04	1.60
R9-1	6.63	2.78	5.42	4.51	3.54
R9-2	6.08	2.63	4.93	4.13	3.22
R9-3	4.29	1.50	2.76	2.20	1.71
R9-4	1.30	0.47	0.82	0.66	0.51

6 HOUR DURATION (Restricted Flow)

Pipe No.	Dia.	Peak Flows (m³/s)				
	m	2 Year	5 Year	10 Year	25 Year	100 Year
489	0.900	1.66	2.17	2.51	2.94	3.57
491	0.900	1.65	2.17	2.51	2.93	3.56
493	1.050	1.65	2.16	2.50	2.93	3.56
495	1.200	1.64	2.15	2.49	2.92	3.55
497	1.050	1.64	2.15	2.49	2.92	3.54
499	1.050	1.64	2.15	2.49	2.92	3.55
501	1.050	1.63	2.15	2.48	2.91	3.54
503	1.050	1.63	2.15	2.48	2.91	3.53
505	1.050	1.63	2.14	2.48	2.91	3.53
507	1.200	1.63	2.14	2.47	2.90	3.53
509	1.200	1.63	2.14	2.47	2.90	3.53
511	1.200	1.62	2.13	2.47	2.90	3.52
513	1.200	1.62	2.13	2.47	2.89	3.52
516	1.200	1.62	2.13	2.46	2.89	3.52
518	1.200	1.62	2.13	2.46	2.88	3.51
520	0.914	2.14	2.53	2.53	2.53	2.53
1001	0.600	0.25	0.26	0.27	0.28	0.29
1002	0.600	0.22	0.22	0.22	0.22	0.22
1003	0.600	0.22	0.22	0.22	0.22	0.22
1004	0.750	0.22	0.22	0.22	0.22	0.22
1005	0.600	0.22	0.22	0.22	0.22	0.22
1006	0.600	0.22	0.22	0.22	0.22	0.22
1007	0.450	0.22	0.22	0.22	0.22	0.22
1008	0.450	0.22	0.22	0.22	0.22	0.22
1009	0.450	0.22	0.22	0.22	0.22	0.22
1010	0.300	0.22	0.22	0.22	0.22	0.22
1011	0.450	0.03	0.04	0.05	0.06	0.07
1012	0.450	0.03	0.04	0.05	0.06	0.07
1101	0.600	0.15	0.20	0.24	0.28	0.33
1102	0.600	0.15	0.20	0.24	0.28	0.33
1103	0.600	0.15	0.20	0.24	0.29	0.33
1104	0.525	0.15	0.21	0.24	0.29	0.33
1105	0.450	0.15	0.21	0.24	0.29	0.33
1200	-	-	-	-	-	-
-	0.750	0.64	0.96	1.13	1.31	1.57
-	0.300	0.06	0.08	0.10	0.11	0.14
1201	0.750	0.70	1.05	1.23	1.43	1.71
1202	0.750	0.48	0.69	0.85	1.05	1.33
1203	0.750	0.48	0.69	0.85	1.05	1.34
1204	0.560	0.28	0.37	0.39	0.39	0.39
1205	0.450	0.28	0.37	0.39	0.39	0.39
1206	0.450	0.28	0.37	0.39	0.39	0.39
1301	0.600	0.25	0.34	0.39	0.47	0.57
1302	0.600	0.14	0.19	0.22	0.26	0.32
1303	0.600	0.14	0.19	0.22	0.26	0.32
1304	0.525	0.07	0.09	0.11	0.13	0.16
1305	0.450	0.07	0.09	0.11	0.13	0.16
1401	0.750	0.34	0.46	0.54	0.64	0.69
1402	0.900	0.34	0.46	0.54	0.64	0.69
1403	0.675	0.34	0.46	0.54	0.64	0.69
1404	0.600	0.34	0.46	0.54	0.64	0.69
1405	0.600	0.34	0.46	0.54	0.64	0.69

6 HOUR DURATION (Restricted Flow)

Pipe No.	Dia. m	Peak Flows (m^3/s)				
		2 Year	5 Year	10 Year	25 Year	100 Year
1406	0.600	0.34	0.46	0.54	0.64	0.69
1407	0.525	0.34	0.47	0.55	0.65	0.79
1408	0.600	0.35	0.47	0.55	0.65	0.80
1501	1.050	0.59	0.59	0.59	0.59	0.59
1502	1.050	0.59	0.59	0.59	0.59	0.59
1503	1.050	0.59	0.59	0.59	0.59	0.59
1504	0.900	0.39	0.39	0.39	0.39	0.39
1505	0.900	0.39	0.39	0.39	0.39	0.39
1506	0.750	1.19	1.57	1.81	2.11	2.53
1507	0.750	1.19	1.57	1.81	2.11	2.53
1508	0.900	1.07	1.42	1.63	1.90	2.29
1509	0.750	1.07	1.42	1.63	1.90	2.29
1510	0.900	1.07	1.42	1.64	1.90	2.30
1601	0.600	0.20	0.20	0.20	0.20	0.20
1602	0.600	0.20	0.20	0.20	0.20	0.20
1603	0.525	0.20	0.20	0.20	0.20	0.20
1604	0.600	0.20	0.20	0.20	0.20	0.20
1605	0.600	0.20	0.20	0.20	0.20	0.20
1606	0.600	0.20	0.20	0.20	0.20	0.20
1607	0.600	0.20	0.20	0.20	0.20	0.20
1608	0.525	0.20	0.20	0.20	0.20	0.20
1609	0.450	0.20	0.20	0.20	0.20	0.20
1610	0.450	0.32	0.32	0.32	0.32	0.32
1611	0.450	0.32	0.32	0.32	0.32	0.32
1701	0.375	0.36	0.36	0.36	0.36	0.36
1702	0.450	0.36	0.36	0.36	0.36	0.36
1703	0.450	0.36	0.36	0.36	0.36	0.36
1704	0.450	0.36	0.36	0.36	0.36	0.36
1705	0.450	0.36	0.36	0.36	0.36	0.36
1706	0.450	0.36	0.36	0.36	0.36	0.36
1707	0.450	0.36	0.36	0.36	0.36	0.36
1708	0.450	0.36	0.36	0.36	0.36	0.36
1709	0.450	0.52	0.52	0.52	0.52	0.52
1710	0.450	0.51	0.51	0.51	0.51	0.51
1711	0.450	0.59	0.81	0.96	0.98	0.98
1712	0.450	0.59	0.82	0.97	0.98	0.98
1801	1.350	0.92	1.32	1.58	1.90	2.31
1802	1.350	0.92	1.32	1.58	1.90	2.32
1803	1.350	0.80	1.15	1.38	1.66	2.07
1804	1.350	0.63	0.93	1.11	1.34	1.68
1805	1.050	0.64	0.93	1.12	1.35	1.69
1901	0.250	0.13	0.18	0.21	0.25	0.25
1902	0.600	0.14	0.18	0.21	0.25	0.31
1903	0.600	0.14	0.18	0.22	0.25	0.31
1904	0.450	0.14	0.19	0.22	0.26	0.31
1905	0.450	0.14	0.19	0.22	0.26	0.31
2001	0.450	0.22	0.30	0.35	0.41	0.47
2002	0.610	0.22	0.29	0.34	0.40	0.47
2100	2.000	0.19	0.26	0.30	0.33	0.33
2101	0.600	0.19	0.26	0.30	0.33	0.33
2102	0.450	0.19	0.26	0.30	0.33	0.33
2103	0.450	0.19	0.26	0.30	0.33	0.33

6 HOUR DURATION (Restricted Flow)

Pipe No.	Dia. m	Peak Flows (m³/s)				
		2 Year	5 Year	10 Year	25 Year	100 Year
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.04	[illegible]
2202	0.750	0.02	0.03	0.03	0.04	0.05
2203	0.750	0.02	0.03	0.03	0.04	0.05
2204	0.750	0.02	0.03	0.03	0.04	0.05
3001	0.425	0.31	0.42	0.49	0.58	0.62
3002	0.425	0.32	0.43	0.50	0.59	0.61
3003	0.425	0.32	0.43	0.50	0.59	0.72
4001	0.300	0.10	0.10	0.10	0.10	0.10
4002	0.450	0.10	0.10	0.10	0.10	0.10
4003	0.450	0.10	0.14	0.16	0.19	0.23
5001	0.450	0.25	0.33	0.39	0.46	0.54
5002	0.450	0.25	0.34	0.39	0.46	0.54
5003	0.450	0.25	0.34	0.39	0.47	0.54
6001	0.530	0.15	0.21	0.24	0.28	0.35
7001	1.200	1.03	1.40	1.63	1.90	2.28
7002	1.200	1.04	1.40	1.64	1.90	2.28
7003	1.200	1.04	1.40	1.64	1.91	2.29
7004	1.200	1.04	1.41	1.64	1.91	2.29
7005	1.200	1.04	1.41	1.64	1.91	2.29
7006	1.050	1.04	1.41	1.65	1.91	2.29
7007	0.900	0.82	1.10	1.28	1.48	1.76
7008	0.900	0.82	1.10	1.29	1.48	1.77
7009	0.750	0.34	0.46	0.54	0.64	0.79
7010	0.685	0.34	0.46	0.54	0.64	0.79
7011	0.685	0.34	0.47	0.55	0.65	0.79
7013	0.750	0.43	0.57	0.66	0.75	0.86
7014	0.600	0.29	0.39	0.45	0.49	0.55
7015	0.450	0.14	0.19	0.22	0.26	0.32
7016	0.450	0.05	0.07	0.08	0.09	0.11
7017	0.450	0.16	0.20	0.23	0.24	0.24
8001	0.600	0.47	0.65	0.76	0.84	0.91
8002	0.450	0.48	0.66	0.77	0.84	0.92
8003	0.450	0.17	0.24	0.28	0.33	0.40
8004	0.450	0.18	0.24	0.28	0.34	0.41
8005	0.450	0.18	0.24	0.29	0.34	0.42
8006	0.450	0.07	0.10	0.12	0.14	0.17
8007	0.450	0.07	0.10	0.12	0.14	0.17
8008	0.450	0.31	0.43	0.50	0.51	0.51
8010	2.000	0.39	0.53	0.62	0.74	0.91
8011	0.600	0.33	0.45	0.53	0.63	0.78
8012	0.600	0.19	0.26	0.31	0.36	0.45
8013	0.600	0.19	0.26	0.31	0.36	0.45
8014	0.600	0.19	0.26	0.31	0.37	0.45
8015	0.600	0.19	0.26	0.31	0.37	0.45
8016	0.600	0.19	0.26	0.31	0.37	0.45
8017	0.600	0.19	0.27	0.31	0.37	0.45
8018	0.450	0.16	0.22	0.25	0.30	0.37
9001	0.450	0.25	0.34	0.40	0.47	0.47
9002	0.450	0.25	0.35	0.41	0.47	0.47
10001	0.525	0.52	0.52	0.52	0.52	0.52
10002	0.525	0.52	0.52	0.52	0.52	0.52
10003	0.525	0.52	0.52	0.52	0.52	0.52

6 HOUR DURATION (Restricted Flow)

Pipe No.	Dia.	Peak Flows (m³/s)				
	m	2 Year	5 Year	10 Year	25 Year	100 Year
10089	0.900	0.64	0.57	0.51	0.94	0.57
10005	0.450	0.52	0.52	0.52	0.52	0.52
20001	1.050	0.64	0.94	1.12	1.36	1.69
20002	0.900	0.64	0.93	1.12	1.36	1.70
R1	15.000	11.91	16.02	18.44	21.35	25.33
R10-1	1.000	0.92	1.32	1.58	1.90	2.31
R10-2	0.900	0.64	0.93	1.12	1.36	1.70
R10-3	3.000	0.54	0.80	0.96	1.16	1.46
R10-4	3.000	0.48	0.71	0.85	1.04	1.30
R10-5	3.000	0.28	0.42	0.51	0.63	0.80
R10-6	3.000	0.22	0.33	0.40	0.49	0.62
R11-1	1.500	4.19	5.72	6.53	7.44	8.74
R11-2	1.500	2.76	3.48	3.73	3.99	4.36
R11-3	1.500	2.52	3.12	3.26	3.42	3.65
R11-4	1.500	2.50	3.10	3.23	3.38	3.61
R11-5	1.500	2.51	3.11	3.24	3.39	3.62
R12	1.000	1.32	1.95	2.39	2.94	3.73
R2	5.000	11.95	16.08	18.50	21.41	25.41
R3	10.000	10.18	13.90	16.03	18.57	22.06
R4-1	8.000	9.72	13.34	15.39	17.84	21.19
R4-2	8.000	8.64	11.77	13.51	15.55	18.29
R5	16.000	8.41	11.45	13.14	15.11	17.77
R6-1	12.000	7.96	10.80	12.33	14.10	16.48
R6-2	12.000	3.81	5.17	6.00	6.91	8.00
R6-3	12.000	2.82	3.82	4.41	5.04	5.76
R7	2.000	1.90	2.51	2.88	3.27	3.70
R8-1	4.000	1.62	2.12	2.41	2.71	3.08
R8-2	4.000	0.93	1.37	1.61	1.87	2.24
R9-1	15.000	1.21	1.45	1.60	1.79	2.03
R9-2	15.000	0.99	1.14	1.24	1.36	1.47
R9-3	15.000	0.86	1.11	1.27	1.46	1.74
R9-4	15.000	0.31	0.45	0.54	0.65	0.82

Note: R#-# - Open Channel Reaches

APPENDIX F

DOCUMENTATION FOR AQUATIC HABITAT ASSESSMENT

ASSESSMENT CRITERIA

1. SPAWNING
    - Known areas of spawning
    - High potential for spawning

2. REARING
    - Off-channel habitat
    - Large Woody Debris
    - Rooted Cutbanks
    - Pools

3. EROSION
    - Existing riprap bank
    - Excessive erosion

4. SEDIMENTATION
    - Excessive sedimentation

5. BARRIERS TO FISH PASSAGE
    - Culverts
    - Debris Barriers
    - Steep slope

6. POINT SOURCE POLLUTION
    - Storm drain outfalls
    - Benthic algae
    - Trash accumulations

7. ENHANCEMENT OPPORTUNITIES
    - Streambank planting
    - Culvert improvement
    - Off-channel habitat
    - Bank stabilization
    - In-stream structures

References:

Global Fisheries Consultants Ltd. 1995. ***Biophysical survey and habitat enhancement of Stoney Creek.*** Report prepared for the Ministry of Transportation and Highways.

Goody, K. 1997. ***A summary of the biophysical and ecological studies of Stoney Creek conducted by the Stoney Creek Environment Committee.*** Report prepared for the SCEC.

Reach #	Length m	Description
❶	611	Brunette R. to Government
❷	280	Government to Loughheed
T1	223	*Tributary # 1* to Gaglardi Way culvert
❸	542	Lougheed to Beaverbrook
❹	772	Beaverbrook to Lyndhurst
T2	216	*Tributary # 2* to Beaverbrook culvert
❺	519	Lyndhurst to Broadway
T3		*Tributary # 3 (lower reach)*
T3a		*Tributary # 3a (south branch)*
T3b		*Tributary # 3b (north branch)*
❻	582	Broadway to North Rd.
❼	85	North Rd. to Chapman
❽		Chapman to Glenayre Pk

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT (FOR STONEY CREEK WATERSHED)

TABLE 1: SPAWNING HABITAT

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-high rating -redds observed	-high value -spawning confirmed	high value and confirmed use by coho, steelhead, and anadromous cuthroat trout
2. Government to Loughheed	-high rating -redds observed	-high value -spawning confirmed	same as above
Tributary # 1	-no comment	-gravel bottom may make it suitable	anadromous cutthroat trout and steelhead spawning confirmed in 1992-93
3. Lougheed to Beaverbrook	-no comment	-potentially good	coho and steelhead use lower part of reach; resident cutthroat trout use entire reach
4. Beaverbrook to Lyndhurst	-no comment	-potential	last known coho spawning was observed in 1980; resident cutthroat spawning throughout reach
Tributary # 2	-no comment	-potential	some known coho use; resident cutthroat use
5. Lyndhurst to Broadway	-no comment	-no comment	some coho use; known resident cutthroat use
Tributary # 3 (lower reach)	-good opportunities	-not surveyed	some potential coho use; known resident cutthroat use
Tributary # 3a (south branch)	-good opportunities	-not surveyed	some potential coho use; known resident cutthroat use
Tributary # 3b (north branch)	-good opportunities	-not surveyed	some potential coho use; known resident cutthroat use
6. Broadway to North Rd.	-no comment	-no comment	some potential coho use; known resident cutthroat use
7. North Rd. to Chapman	-no comment	-no comment	limited use by coho in lower section; isolated use by cutthroat
8. Chapman to Glenayre Pk	-no comment	-no comment	no utilization

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT
(FOR STONEY CREEK WATERSHED)

TABLE 2: REARING HABITAT

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-high rating	-high value	-high value
2. Government to Loughheed	-high rating	-high value	-high value
Tributary # 1	-low rating	-suitable	-low to moderate value -most fish found near culvert pool -overall low channel complexity
3. Lougheed to Beaverbrook	-high rating	-good potential	-lower third has a high value; remainder is low to moderate -middle section is quite channelized, lacking channel complexity
4. Beaverbrook to Lyndhurst	-high rating to School -low rating above School	-rated as marginal	-low to moderate -channelization has significantly increased since high flow events of January 1997.
Tributary # 2	-low rating	-has great potential	-low value but high potential for enhancement
5. Lyndhurst to Broadway	-low rating	-rated as marginal	-low rating
Tributary # 3 (lower reach)	-medium to high	-not surveyed	-medium to high
Tributary # 3a (south branch)	-medium	-no surveyed	-medium
Tributary # 3b (north branch)	-medium to high	-no surveyed	-medium to high
6. Broadway to North Rd.	-low rating	-poor to marginal	-low rating
7. North Rd. to Chapman	-low rating	-less favorable	-low rating
8. Chapman to Glenayre Pk	-low rating	-marginal to acceptable	-low rating but good potential rearing for cutthroat -good rearing pools downstream of school

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT (FOR STONEY CREEK WATERSHED)

TABLE 3: EROSION

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-bank erosion d/s of BNR culvert	-serious bank erosion -8sites, 206m	-two significant sites; one near BNR and the other ca. 200 metres downstream
2. Government to Loughheed	-not observed	-not observed	-large tree down near side channel -significant erosion immediately downstream of Loughheed culvert where riprap was placed along bank
Tributary # 1	-not observed	-severe bank erosion at storm drains	-not much erosion observed
3. Lougheed to Beaverbrook	-not observed	-existing riprap -large gully -1site, 3m	-lower section has had riprap since 1993 -debris screen has been blocked resulting in significant erosion along rail road and stream bank
4. Beaverbrook to Lyndhurst	-existing large riprap armoring on east bank	-serious bank erosion -17sites, 131m	-bank erosion underneath Beaverbrook overpass and in park
Tributary # 2	-not observed	-90% of banks eroded due to path	-90% of banks eroded due to path
5. Lyndhurst to Broadway	-channelized stream bed	-existing riprap and eroding banks -13sites, 262m	-existing riprap and eroding banks -riprap is needed to protect sewer line; weirs are required to control flow velocities and reduce erosion
Tributary # 3 (lower reach)	-not observed	-not surveyed	-eroding clay bank and large fallen tree
Tributary # 3a (south branch)	-not observed	-not surveyed	-no observations
Tributary # 3b (north branch)	-not observed	-not surveyed	-no observations
6. Broadway to North Rd.	-exsiting riprap -eroding clay banks	-much riprap and erosion -8sites, 211m	-much riprap and erosion -rock weirs are required to control flow velocities and reduce erosion
7. North Rd. to Chapman	-steep ravine with some slumping noted	-unstable stream banks	-unstable stream banks
8. Chapman to Glenayre Pk	-not observed	-not surveyed	-relatively stable channel

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT
(FOR STONEY CREEK WATERSHED)

TABLE 4: SEDIMENTATION

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-not observed	-1site, 16m	-unusually high runoff events in January 1997 resulted in significant increases in sedimentation
2. Government to Loughheed	-not observed	-not observed	-not observed
Tributary # 1	-not observed	-1site, 6m	-significant sedimentation below East Lake Drive culvert
3. Lougheed to Beaverbrook	-sandy bottom noted	-not observed	-significant washouts and sedimentation due to January 1997 runoff events -bed sediment above grill is 1 foot deep
4. Beaverbrook to Lyndhurst	-not observed	-17sites, 131m -clay banks	-clay banks -shifting, mobile sediments in park
Tributary # 2	-not observed	-fine sediments noted on top of substrate	-fine sediments noted on top of substrate; source is upstream
5. Lyndhurst to Broadway	-not observed	-13sites, 262m	-no comments
Tributary # 3 (lower reach)	-sediment source from eroding banks and bike paths	-not surveyed	-no comments
Tributary # 3a (south branch)	-not observed	-not surveyed	-no comments
Tributary # 3b (north branch)	-not observed	-not surveyed	-some sedimentation noted due to mountain bike activity
6. Broadway to North Rd.	-high potential for sediment transport from clay banks	-8sites, 211m	-existing comments apply
7. North Rd. to Chapman	-slumping ravine a likely source of future siltation	-not observed	-existing comments apply
8. Chapman to Glenayre Pk	-not observed	-not observed	-existing comments apply

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT (FOR STONEY CREEK WATERSHED)

TABLE 5: BARRIERS TO FISH MOVEMENT

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-no barriers	-no barriers	-existing comments apply
2. Government to Loughheed	-no barriers	-no barriers	-existing comments apply
Tributary # 1	-Eastlake Drive culvert	-Eastlake Drive culvert	-culvert underneath sewer line is a potential problem because it can become plugged
3. Lougheed to Beaverbrook	-no barrier	-no barrier	-Lougheed culvert is a barrier for the upstream movement of juvenile fish
4. Beaverbrook to Lyndhurst	-no barrier	-no barrier	-existing comments apply
Tributary # 2	-Beaverbrook Cres. culvert	-Beaverbrook Cres. culvert	-existing comments apply
5. Lyndhurst to Boardway	-no barrier	-no barrier	-existing comments apply
Tributary # 3 (lower reach)	-no barrier	-not surveyed	-existing comments apply
Tributary # 3a (south branch)	-Gaglardi Way culvert	-not surveyed	-Gaglardi Way culvert has been replaced and is no longer a barrier to fish movement
Tributary # 3b (north branch)	-auto wreck at old pipeline ROW, 473m	-not surveyed	-existence of car wreck needs to be confirmed
6. Broadway to North Rd.	-no barrier	-no barrier	-existing comments apply
7. North Rd. to Chapman	-9% slope -0.6m barriers -Chapman culvert	-not surveyed	-existing comments apply
8. Chapman to Glenayre Pk	-above limit of access	-not surveyed	-existing comments apply

DOCUMENTATION OF AQUATIC HABITAT ASSESSMENT
(FOR STONEY CREEK WATERSHED)

TABLE 6: POINT SOURCE POLLUTION

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-none observed	-none observed	-RV park is a source of garbage -dog droppings are a problem
2. Government to Loughheed	-none observed	-none observed	-existing comments apply
Tributary # 1	-poor water quality -substrate orange stained	-large amount of trash -foam/soap	-existing comments apply -source of pollution may be the truck wash north of Eastlake Drive and west of Gaglardi Way
3. Lougheed to Beaverbrook	-none observed	-none observed	-sewer manhole on creek bank may be a potential source of sewage when flooding occurs
4. Beaverbrook to Lyndhurst	-none observed	-none observed	-a fish kill has occurred in the past when residents emptied their swimming pool
Tributary # 2	-none observed	-severe domestic pet waste	-existing comments apply
5. Lyndhurst to Broadway	-none observed	-none observed	-existing comments apply
Tributary # 3 (lower reach)	-good water quality	-not surveyed	-existing comments apply
Tributary # 3a (south branch)	-good water quality	-not surveyed	-existing comments apply
Tributary # 3b (north branch)	-good water quality	-not surveyed	-existing comments apply
6. Broadway to North Rd.	-apparent high nutrient loading	-garden wastes observed	-existing comments apply
7. North Rd. to Chapman	-landscaped banks are a potential source of fertilizer	-lawns to creek bank	-existing comments apply
8. Chapman to Glenayre Pk	-grassy park is a likely source of fertilizer	-not surveyed	-existing comments apply -effects of road runoff may be significant in this reach

TABLE 7: ENHANCEMENT OPPORTUNITIES

Reach	Global Fisheries 1995	SCEC 1997	Expert Workshop May 1998
1. Brunette R. to Government	-no recommendation	-no recommendation	-fencing is needed around RV park -small oxbow should be maintained
2. Government to Loughheed	-no recommendation	-no recommendation	-improve existing side-channel compensatory site
Tributary # 1	-no recommendation	-address erosion -storm drain marking	-sanitary sewer should be lowered below creek bed or small inverted siphon culvert underneath sewer line -meandering and complexing with LWD and pools -widen creek bed with acquisition of BNR property -biofiltration for storm sewer effluents -augment base flow during low flow season
3. Lougheed to Beaverbrook	-no recommendations	-placement of LWD -side channels	-baffles for Lougheed culvert -correct erosion of east side tributary u/s of Lougheed -create off-channel habitat and wetland biofiltration -GVRD access road needs riparian plantings
4. Beaverbrook to Lyndhurst	-no recommendation	-stabilize clay banks	-fix major bends that have bank erosion -decommission trail
Tributary # 2	-no recommendation	-relocate path -streamside planting naturalize u/s channel	-improve drainage on school playing -create off-channel habitat on east side of Stoney Creek as per proposed habitat compensation
5. Lyndhurst to Boardway	-no recommendation	-decr. ROW width -streambank planting -more instream hab. -off-channel habitat -stabilize banks	-west bank needs to be stabilized to arrest downslope movement of soil -existing weir will be replaced by GVRD
Tributary # 3 (lower reach)	-no recommendation	-no recommendation	-address clay bank erosion
Tributary # 3a (south branch)	-replace hanging culvert at Gaglardi	-no recommendation	-culvert has been replaced
Tributary # 3b (north branch)	-construct pools -repair bike path -remove car wreck	-no recommendation	-Burnaby Mountain Management Plan must address the problem with mountain bikers
6. Broadway to North Rd.	-plant trees along bank	-public education and signage	-access road should be fenced to discourage trash tipping -create route into park for spillway & off-channel habitat -two rock weirs will be upgraded by GVRD
7. North Rd. to Chapman	-no recommendation	-no recommendations	-existing comments apply
8. Chapman to Glenayre Pk	-no recommendations	-no recommendations	-existing comments apply

APPENDIX G

BRIEFING PAPER ON RUNOFF QUALITY SAMPLING PROGRAM

KWL-CH2M

Kerr Wood Leidal-CH2M Hill Inc.
139 West 16th Street, North Vancouver
British Columbia, Canada V7M 1T3
TEL: 604.985.5361
FAX: 604.985.3705 EMAIL: kwl@kwl.bc.ca

CONSULTING
ENGINEERS
ENVIRONMENTAL
PLANNERS

April 21, 1998

Stoney Creek Project Steering Committee
c/- Lambert Chu, P.Eng., Chairman
City of Burnaby
4949 Canada Way
Burnaby, B.C.
V5G 1M2

Dear Sir:

Re: STONEY CREEK STORMWATER MANAGEMENT PLAN
Runoff Quality Assessment & Selection of BMPs for Treatment
Submission of Briefing Paper on Sampling Program
Our File No. 1045.002C

We take pleasure in forwarding ten (10) copies of our interim report titled *Briefing Paper on A Proposed Runoff Quality Sampling Program for Stoney Creek Watershed* for distribution to the members of the Steering Committee. The program was developed by Ron Kistritz and reviewed with Dr. Ken Hall.

Assessment of baseline water quality is a 3-step process, with the first step being development of a sampling strategy. The second step is to implement the sampling program. The third step is to analyze the results.

The Briefing Paper provides a context for the sampling program by highlighting the fact that the results of the runoff quality assessment will provide a basis for selection of BMPs for urban runoff treatment. To select appropriate BMPs, it is first necessary to identify the resources being protected, the threats to those resources, and the alternative BMPs.

Of significance, we have been able to scale back the scope of the laboratory testing. It is proposed to reallocate the budget saving to the hydrology component of the study. Environmental impacts result from *changes in hydrology.* Mitigating those changes would also reduce pollutant loading, and thereby protect the beneficial uses of the Stoney Creek system.

Yours very truly,

KERR WOOD LEIDAL - CH2M HILL INC.

Kim A. Stephens, M.Eng., P.Eng.
Project Manager

KAS/ T:\1045-002.C\BRIEFING.PPR\TRANSMTL.WPD

CITY OF BURNABY
STONEY CREEK PROJECT STEERING COMMITTEE

BRIEFING PAPER

ON

A PROPOSED RUNOFF QUALITY SAMPLING PROGRAM FOR STONEY CREEK WATERSHED

DRAFT FOR DISCUSSION

APRIL 1998

Our File No. 1045.002C

KERR WOOD LEIDAL-CH2M HILL INC.
A Joint Company of Kerr Wood Leidal Associates Ltd. And CH2M Gore & Storrie Ltd.

STONEY CREEK PROJECT STEERING COMMITTEE
BRIEFING PAPER ON A PROPOSED RUNOFF QUALITY
SAMPLING PROGRAM FOR STONEY CREEK WATERSHED

CONTENTS

TABLES

TABLE 1

THE BUILDING BLOCKS FOR A STONEY CREEK INTEGRATED STORMWATER MANAGEMENT PLAN

PART	DESCRIPTION	SCOPE OF COMPONENT
A	Storm Runoff Control	The focus is on mitigating flood and erosion damage resulting from peak flows during major storm/runoff events (i.e., Q_{10} and Q_{100})
B	Aquatic Habitat Protection and Enhancement Evaluation	This involves development of a strategy for ensuring the *environmental health* of major streamside resources, including both riparian and in-stream habitat.
C	Runoff Quality Control	The primary focus is on water quality for aquatic life, with particular emphasis on developing guidelines for the preservation of water quality in Stoney Creek for fish habitat.
D	Consensus-Building	This involves working with the Steering Committee to develop a shared vision regarding the achievable goals for watershed and stream corridor management.

STONEY CREEK PROJECT STEERING COMMITTEE
BRIEFING PAPER ON A PROPOSED RUNOFF QUALITY SAMPLING PROGRAM FOR STONEY CREEK WATERSHED

1. INTRODUCTION

1.1 Overview of Study Components

The stated purpose of the study is to analyze the adequacy of existing drainage facilities, and to develop detailed guidelines and options for runoff control and aquatic enhancement, with the goal of preserving the existing streams in their natural state. Thus, the ultimate deliverable under this study is an *Integrated Stormwater Management Plan for Stoney Creek*. Development of the plan involves integration of the four components as summarized in Table 1.

1.2 Scope of Runoff Quality Assessment

The "runoff quality control" component comprises two distinct sub-components as summarized below:

- **Baseline Quality:** Carry out a water quality sampling program to characterize existing conditions.
- **Environmental Priorities:** Develop guidelines for future in-stream environmental protection and enhancement programs.

The results of the runoff quality assessment provide a basis for selection of BMPs (Best Management Practices) for urban runoff treatment. Hence, the reason for linking the two in the proposed title for this component of the study. (Reference: our proposal submission dated February 1998)

To select appropriate BMPs, it is first necessary to identify the resources being protected, the threats to those resources, and the alternative BMPs.

1.3 Description of Work Program for Water Quality Sampling and Analysis

Purpose and Rationale

Assessment of baseline water quality is a 3-step process, with the first step being development of a *Runoff Quality Sampling Strategy*. The second step is to implement the sampling program. The third step is to analyze the results.

TABLE 2

WORK PROGRAM FOR RUNOFF QUALITY COMPONENT

TITLE OF DOCUMENT	SCOPE OF DOCUMENT
Runoff Quality Assessment and Selection of BMPs for Urban Runoff Treatment	▸ Review the available database on runoff quality monitoring for the Brunette River basin, and develop a strategy for runoff quality sampling in the Stoney Creek system ▸ Carry out a grab sampling program to provide a "snapshot" of baseline conditions at three different times during the study time-frame ▸ Develop guidelines for minimizing the impact of urban development and/or redevelopment on runoff quality, aquatic and terrestrial habitat ▸ Identify types of physical, structural, and management BMPs that would be appropriate for conditions in the Stoney Creek drainage area ▸ Assess the regulatory implications for local government in taking on responsibility for adopting and enforcing bylaws that extend municipal regulation.

The purpose of this *Briefing Paper* (Step #1) is to outline a meaningful and cost-effective water quality sampling program within the timeframe of the study program (Step #2).

The rationale for the water quality sampling strategy is based on a review of published information (Macdonald et.al. 1997), existing water quality data records (McCallum 1995), and consultations with Dr. K.J. Hall (Institute for Resources and Environment, Westwater Research Unit, UBC).

The final deliverable will be a document titled *Runoff Quality Assessment and Selection of BMPs for Urban Runoff Treatment* (Step #3). Table 2 summarizes the anticipated scope of this document. The reader is referred to Section 5 for a "look ahead" regarding the expected output for the runoff quality component of the overall stormwater management study.

Identification of Objectives

The objective of the water quality sampling program is to provide a "snap-shot" of the runoff quality of Stoney Creek from non-point sources and to develop guidelines for the preservation of water quality in the creek for fish habitat.

By including total fecal coliforms as a water quality measure, we have expanded the objectives to include human health concerns along with the focus on aquatic life. Our study objectives will focus on baseflow conditions and stormflow events. Recognizing the difficulty in successfully capturing a storm event during the sampling period of May and June, we will utilize an automatic water sampling device.

The baseflow sampling program is designed to address the following questions:

- What are the current water quality conditions and how do they compare to past data?
- How do conditions in the upper watershed compare to those downstream?
- How does the water quality of Stoney Creek compare to that of the Brunette River.

The stormflow sampling program is designed to address the following questions:

- What is the contaminant load associated with stormflow events in May and June?
- What is the relationship between total suspended sediments and turbidity?

Finally, it is anticipated that the results of the runoff quality assessment will provide a basis for selection of BMPs for urban runoff treatment.

Background on Previous Water Quality Investigations

The Stoney Creek watershed was sampled in 1978 (McNeill 1978) and again in 1994 (Hall 1994, Macdonald et.al. 1997) as part of environmental quality studies that covered stations over the entire Brunette River watershed.

Water quality sampling on the Stoney Creek watershed focused on water quality measurements taken during baseflow (BF) conditions or dry weather periods when there were no storm events. Samples were taken on a weekly basis in 1973 and on a monthly basis in 1994. A few samples were also taken of stream sediments and biota.

In the Stoney Creek system, baseflow measurements have been taken at two locations:

- At Grandview (Lougheed) Hwy., 100 m west of Hunter/Keswick intersection
- At E. Broadway, 50 m west of Norcrest Rd.

The proposed water quality sampling program is based on a quick review of the past water quality trends and observations in order to help identify which parameters should be the focus of this study. A complete discussion of water quality conditions in the Brunette and Stoney Creek watersheds will be provided in this study's final report.

2. DESCRIPTION OF PROPOSED SAMPLING STRATEGY

2.1 Selection of Sampling Stations

We propose to use the upstream sampling station that has been used in past water quality studies and the location currently being used for the GVRD hydrometric station. Those stations are strategically located to capture the upstream reach of the watershed and the two major westside tributaries. Using those stations will allow comparisons with the historical water quality and hydrological database, and provide more accurate assessments of stormwater contaminant loading. The water quality sampling stations on Stoney Creek will be as follows:

- Government Street, north side at the GVRD Gauging Station
- At E. Broadway, 50 m west of Norcrest Rd.

For the purpose of comparing base flow water quality data, we will include a station on the Brunette River immediately upstream of Stoney Creek; namely: *Brunette River at Cariboo Road.*

2.2 Sampling Frequency

Baseflows

Baseflow samples will be taken manually at three stations (Grandview, East Broadway, and Cariboo) once in May and once in June.

Stormwater Flows

Since there is already historic information available on baseflow water quality conditions for May and June, our water quality sampling program will focus primarily on stormflow events. In order to obtain as much useful stormwater data as possible, we will utilize an American Sigma automatic water sampler. The sampler will be secured at the GVRD gauging station on Government Street.

The automatic sampler will be programmed to sample storm events based on hydrometric data analyzed from the GVRD flow monitoring station at Government Street. The auto-sampler will collect a total of 24 - 500 ml samples at predetermined time intervals (e.g., 15 to 30 minutes) over a total sampling period of several hours (e.g., 6 to 10 hours).

Flow-proportioned samples will be used to prepare a composite sample which will be used to derive a measure of the storm's contaminant loading. We will prepare to sample over a total of four storm events.

For one of the storm events we will analyze the individual samples for total suspended sediments in order to derive a relationship between total suspended sediments.

2.3 Hydrometric Measurements

Flow measurements will be measured at the GVRD gauging station from which we can calculate flow based on GVRD's preliminary stage-discharge equation.

3. SELECTION OF WATER QUALITY PARAMETERS

3.1 Temperature, D.O., pH, and Conductivity

We will measure temperature, pH, and conductivity in baseflow and stormflow samples. Past water quality measures have shown that Stoney Creek dissolved oxygen (D.O.) levels are amongst the highest in the Brunette River system. Therefore, we will not include D.O. measurements in this study.

3.2 Suspended Solids

The majority (>50%) of trace metals and hydrocarbon are associated with suspended solids. We will include measurements of total suspended solids in baseflow and stormflow samples since this parameter is one of the best indicators of run-off water quality. For one of the storm events we will analyze all of the 24 discrete samples taken by the auto-sampler in order to develop a relation between turbidity and total suspended solids.

3.3 Turbidity

Turbidity will be measured for the purpose of developing a relationship between this relatively simple and inexpensive measure and total suspended sediments. This relationship would be very useful for any future water quality monitoring programs on the Stoney Creek system. Turbidity will be measure continuously with an Analite sensor connected to a data logger.

3.4 Nutrients

On the basis of past water quality data, the best nutrient indicator for Stoney Creek has been nitrate. We will therefore include nitrate as a measure in our baseflow and stormflow samples.

3.5 Fecal Coliforms

Past studies have shown that fecal coliform levels increased in Stoney Creek from upstream to downstream. We will therefore include this measure to obtain further information on the trends and patterns of fecal contaminants. Since fecal coliform samples require sterilized glass bottles, this measure will be undertaken for manual baseflow samples only.

3.6 Trace Metals

Trace metals measured in Stoney Creek in past studies showed the highest concentrations for copper, zinc, and manganese. We will therefore include these trace metals in our baseflow and stormflow sample testing.

3.7 Oxygen Consuming Substances

Past studies in the Brunette watershed have shown that the easily degraded component of COD (i.e., BOD) represents less than 10%. Neither of these parameters has been tested in Stoney Creek water. We will include COD in our baseflow and stormwater samples.

3.8 Hydrocarbons

Hydrocarbons have not been measured in Stoney Creek. However stormwater analyses at other locations in the Brunette system have shown high concentrations of hydrocarbons associated with stormwater solids. We will therefore include a measure of total extractable hydrocarbons in our water samples. Only manual baseflow samples will be included since they require acid rinsed glass bottles.

3.9 Numbers of Samples

The run-off quality parameters and number of samples will be as follows:

PARAMETER	BASE FLOW SAMPLES	STORM FLOW SAMPLES
Field Measurements		
pH		
Temperature		
Conductivity		
Laboratory Analyses		
Total suspended sediments	6	27
Nitrate Nitrogen	6	4
Chemical oxygen demand	6	
Total extractable hydrocarbons	6	
Copper	6	4
Manganese	6	4
Zinc	6	4
Total & Fecal coliforms	6	
Total Samples	48	43

4. BUDGET FOR LABORATORY ANALYSES

Based on the information presented in Section 3, the revised analytical budget for the runoff quality study component is as follows:

PARAMETER	BASE FLOW SAMPLES	STORM FLOW SAMPLES	COST PER SAMPLE	SUBTOTAL	DETECTION LIMIT (mg/L)
Field Measurements					
pH				$ 50.00	N.A.
Temperature				$ 50.00	N.A.
Conductivity				$ 50.00	N.A.
Subtotal				$ 150.00	
Laboratory Analyses					
Total suspended sediments	6	27	$ 12.00	$ 396.00	1
Nitrate Nitrogen	6	4	$ 15.00	$ 150.00	
Chemical oxygen demand	6	4	$ 25.00	$ 250.00	20
Total extractable hydrocarbons	6	0	$100.00	$ 600.00	1
Copper	6	4	$ 12.00	$ 120.00	0.001
Manganese	6	4	$ 8.00	$ 80.00	0.001
Zinc	6	4	$ 8.00	$ 80.00	0.005
Total & Fecal coliforms	6	0	$ 35.00	$ 210.00	1(FU)
Subtotal	48	47			
Total Cost				**$ 2,186.00**	

This compares with the original budget estimate of $10,430 for water quality testing as detailed in our February 1998 proposal submission. The revised budget reflects our review of the available information base, and has been verified in consultation with Dr. Ken Hall of UBC. We believe the scaled-down program results in better value for the dollar.

It is proposed to reallocate the resultant saving to the hydrology component of the study. As highlighted in our February 1998 submission, a key to developing an effective environmental protection strategy for streams is having a proper appreciation for the environmental impacts resulting from *changes in hydrology.* Mitigating those changes in hydrology would also reduce pollutant loading, and thereby protect the beneficial uses of the Stoney Creek system.

TABLE 3

ASSESSMENT AND SELECTION OF BMPS FOR URBAN RUNOFF TREATMENT

TOPIC	SCOPE OF DISCUSSION
BMP Classifications	▸ Develops a common understanding of BMPs by describing the three categories of controls. ▸ Sets a tone for customizing a BMP strategy to suit conditions in the Stoney Creek watershed.
Overview of Natural Conditions	▸ Identifies the ecological resources to be protected by a BMP strategy. ▸ Highlights the local hydrological factors that may have a significant bearing on the elements of a BMP strategy.
Assessment of Land Uses and Activities	▸ Focuses on the land use conditions in the study area that are unusual from an urban stormwater management perspective. ▸ Assesses the impact of construction, and park maintenance activities on sediment and pollutant discharges to receiving waters.
Regulatory Options for Source Control Management	▸ Discusses the implications of Provincial legislation that now enables municipalities to adopt bylaws for the purpose of regulating environmental stewardship. ▸ Identifies the challenges that are implicit in venturing into uncharted territory.
Framework for a BMP Strategy	▸ Develops the framework for the *Environmental Protection Component* of an integrated stormwater management strategy. ▸ Provides specific details regarding BMPs that would be appropriate, and suggest regulations for runoff control in new development areas.
Integration of BMPs and Urban Hydrology	▸ Illustrates how the progressive *changes in hydrology* that result from an increasing percentage of impervious area and road densification can be mitigated. ▸ Reviews the linkage between runoff quality BMPs and hydrologic modelling.

5. A LOOK AHEAD

5.1 Expected Study Output

We anticipate that our water quality sampling program will at least provide a snapshot of the baseline water quality conditions that can be encountered in Stoney Creek under various flow regimes.

Our review of historical water quality data along with the results of the water quality sampling program will enable us to focus on water quality issues and concerns that are specific to the Stoney Creek system. We will also be able to develop recommendations and guidelines for the most significant run-off pollutants or sub-systems with the greatest problems.

In order to fill remaining data gaps and to provide a more comprehensive and longer-term water quality overview, we will recommend where further sampling initiatives are required and how those needs can best be addressed.

5.2 Classification of BMPs

BMPs are physical, structural and managerial practices that prevent or reduce *water pollution* and *changes in hydrology*. Stormwater BMPs can be grouped into source controls, treatment controls, and streambank erosion controls.

Many people are still unaware of how their activities may affect runoff quality. Thus, any program of BMPs must begin with an effective program of education. To be effective, the education must be targeted to specific audiences, must explain cause and effect, include specific recommended actions, and must convince people that their actions can make a difference.

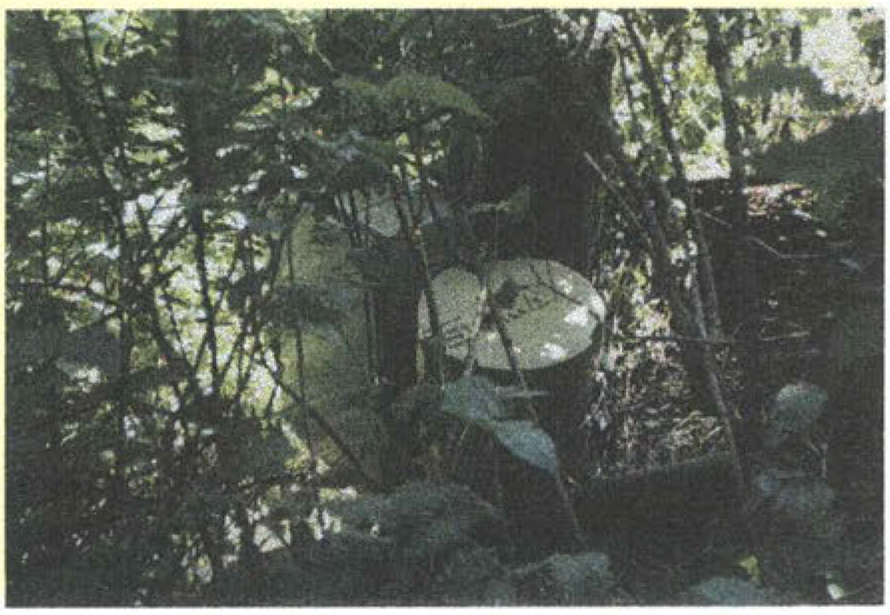
5.3 Learning from the Kelowna Experience

Building on our Washington State experience, we have customized a "BMP strategy" for the City of Kelowna that lends itself to phased implementation as follows:

- **Step #1:** Invest in public education, maintenance management programs, and source control regulations first.
- **Step #2:** Monitor the foregoing activities to assess their effectiveness in addressing runoff quality concerns, problems and issues.
- **Step #3:** If source control BMPs are not sufficient, then selectively invest in capital improvements to address specific problems.

Applying the Kelowna experience, Table 3 highlights topics that could be covered in the final report in addition to presenting the results of the water quality sampling program.

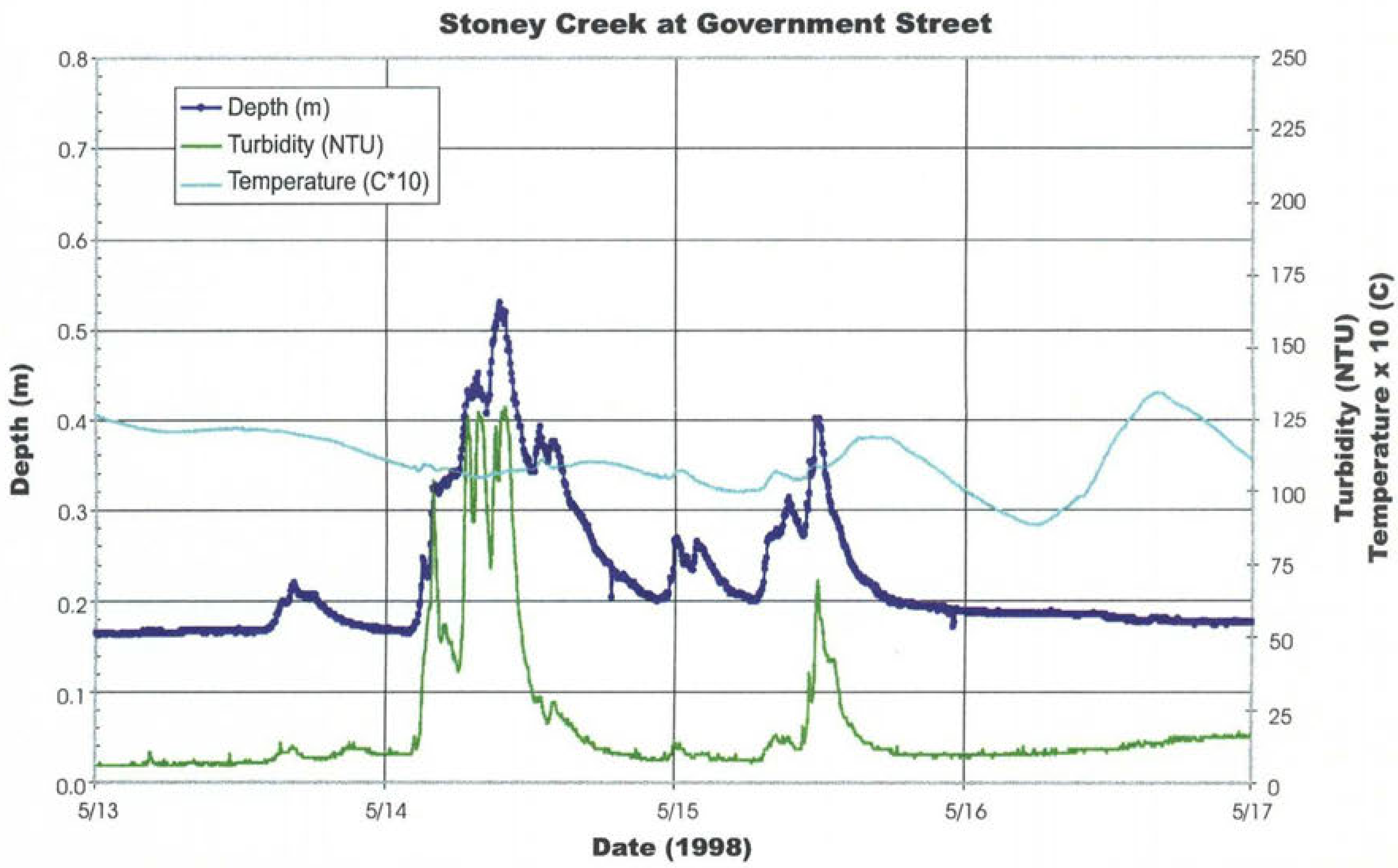
STONEY CREEK UPSTREAM FROM GOVERNMENT STREET



HYDROMETRIC KIOSK & FLOW SAMPLER

HYDROMETRIC KIOSK MOUNTED ON ABUTMENT WITH PVC SENSOR EXTENSION

GVRD ULTRASONIC DEPTH GAUGE OVER WEST CULVERT



STONEY CREEK WATER QUALITY SAMPLING STATION

KWL CH2M
CONSULTING ENGINEERS
ENVIRONMENTAL PLANNERS

APPENDIX H

RESULTS OF LABORATORY ANALYSIS OF RUNOFF SAMPLES

BASEFLOW WATER QUALITY

May 20th 1998

Water Quality Parameter	Stoney Ck. Broadway Ave.	Stoney Ck. Government St.	Brunette R. Cariboo Rd.
Total Suspended Solids	26	2	5
Nitrate Nitrogen	0.866	0.744	0.175
Fecal Coliform Bacteria	42	78	448
Total Coliform Bacteria	TNTC	209	TNTC
Copper	0.001	0.001	0.003
Manganese	0.018	0.032	0.140
Zinc	<0.005	<0.005	<0.005
Total Ext. Hydrocarbons	<1	<1	<1
Chemical Oxygen Demand	<20	<20	<20

June 17th 1998

Water Quality Parameter	Stoney Broadw.	Stoney Govt.	Brunette Cariboo
Total Suspended Solids	<1	1	9
Nitrate Nitrogen	0.827	0.643	0.172
Fecal Coliform Bacteria	80	133	268
Total Coliform Bacteria	598	267	380
Copper	0.002	<0.002	<0.002
Manganese	0.015	0.019	0.155
Zinc	<0.005	<0.005	<0.005
Total Ext. Hydrocarbons	<1	<1	<1
Chemical Oxygen Demand	20	<20	28

Results are expressed as mg/L except where noted
< less than the detection limit indicated
Coliform results are expressed as Colony Forming Units (CFU) per 100 ml

STORMWATER QUALITY

May 24th 1998

Water Quality Parameter	Results
Total Suspended Solids	222
Nitrate Nitrogen	0.415
Copper	0.017
Manganese	0.480
Zinc	0.074
Chemical Oxygen Demand	82

June 10th 1998

Water Quality Parameter	Results
Total Suspended Solids	38
Nitrate Nitrogen	0.673
Copper	0.010
Manganese	0.150
Zinc	0.027
Chemical Oxygen Demand	44

June 24th 1998

Water Quality Parameter	Results
Total Suspended Solids	65
Nitrate Nitrogen	0.410
Copper	0.008
Manganese	0.150
Zinc	0.026
Chemical Oxygen Demand	43

Results based on a flow-proportioned composite sample derived from 25 discrete samples taken over the course of the ca. 10 hour duration storm events.
Results are expressed as mg/L except where noted
< less than the detection limit indicated

TOTAL SUSPENDED SOLIDS (mg/L) AND TURBIDITY (NTU)

May 24th 1998

Sample I.D.	Time	TSS	Turbidity
SG2-1	12:45	112	5.6
SG2-2	13:00	78	43.2
SG2-3	13:15	52	35.5
SG2-4	13:30	48	26.6
SG2-5	13:45	35	19.3
SG2-6	14:00	40	16.7
SG2-7	14:15	29	20.6
SG2-8	14:30	23	15.5
SG2-9			
SG2-10	15:00	19	14.2

May 25th 1998

Sample I.D.	Time	TSS	Turbidity
SG2-3	2315 (May 24)	468	207
SG2-4	2330 (May 24)	1200	483
SG2-5	2315 (May 24)	950	354
SG2-6	0000	454	219
SG2-10	0100	90	39.0
SG2-11	0115	232	95.0
SG2-12	0130	715	331
SG2-13	0145	232	103
SG2-14	0215	186	83.0
SG2-15	0245	92	36.0
SG2-16	0315	40	26.0
SG2-17	0345	24	18.0
SG2-18	0415	72	35.0
SG2-19	0445	44	20.0
SG2-20	0515	32	16.0

June 24th 1998

Sample I.D.	Time	TSS	Turbidity
KWL-1	0250	164	83.7
KWL –2	0305	161	114
KWL –3	0320	169	90.4
KWL –4	0335	141	118
KWL –5	0350	266	121
KWL –6	0405	262	112
KWL –7	0420	185	81.8
KWL –8	0435	107	76.1
KWL –9	0450	151	65.9
KWL-10	0505	132	59.3
KWL-11	0520	101	49.2
KWL-12	0535	83	40.3
KWL-22	1020	59	31.0