A GIS EVALUATION OF LAND USE DYNAMICS AND FISH HABITAT IN THE SALMON RIVER WATERSHED - LANGLEY, B.C.

by

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ABSTRACT

With increased urban development in the Fraser River Basin, it is expected that fish habitat degradation will become more widespread bringing into question the sustainability of the fisheries resource. This thesis examines the dynamics of land use and fish habitat in the Salmon River watershed located in the Lower Fraser River Valley. The study was initiated to: 1) quantify the distribution and recent trends in land use changes; 2) identify and quantify critical fish habitat to provide a basis for assessing habitat deterioration in the future; 3) characterize recent fish habitat changes; and 4) describe trends and processes associated with fish habitat and streamside land use relationships. Geographic Information System techniques were used to analyze the land use data and to display the results.

The distribution and temporal changes in land use from 1979-80 to 1989-90 are examined in three ways: 1) an evaluation of overall watershed conditions; 2) an evaluation of a 500 meter buffer zone of the stream network; and 3) an evaluation of 500 meter buffer segments of four key fish habitat reaches.

A significant decrease in agriculture, a substantial increase in undeveloped areas, and a modest increase in residential development were measured over the 10 year period for both the overall watershed and the stream network buffer. Similar land use trends were observed for the four key fish habitat buffer segments. A large increase in residential development was particularly notable in two of the four buffer

segments.

Stream morphology characteristics were measured in prime fish habitat areas of the Salmon River, and its principle tributary Coghlan Creek. The fish habitat was classified into four hydraulic unit types; riffles, glides, pools and sloughs. A comparison of reaches between the two streams showed that the Salmon River had twice the stream volume relative to Coghlan Creek. The reaches selected for study within the two streams are considered the most critical spawning and rearing areas for salmonids in the basin. Measurements of preferred hydraulic habitat for salmonids (riffles, glides and pools) showed that Coghlan Creek had 20% more high quality habitat than the Salmon River.

A interesting 2:1 relationship was found between reaches in the Salmon River and Coghlan Creek for both stream volume and smolt catch numbers. This ratio was consistent for five years between 1979 and 1989 for which reliable data is available. However in 1990 and 1992, smolt catch statistics decreased by half in the Salmon River which coincides with significant increases in urbanization. More information is needed to document these trends and to provide evidence for cause and effect relationships.

The techniques used in this study provide a new approach for examining potential interactions and relationships between land use, fish habitat and fish production. The study contributes a set of baseline data which can be used for future monitoring of fish habitat dynamics in relation to land use changes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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Finally, and most important of all, my deepest appreciation is reserved for "A. M." Debruyn, who kept me "balanced" during times when it all seemed unreasonable.

DEDICATION

This thesis is dedicated to the late A. J. Hilton who introduced me to the art of fishing and the concept of fisheries conservation.

CHAPTER 1

INTRODUCTION

The salmonids and other fish stocks that frequent the Fraser River Basin make up a very complex web of spawning and rearing processes in the freshwater and estuarine environments. To manage the fish and these environments is an extremely difficult task, especially if one considers the increasing number of competing resource users in the basin. To compound the problem, many freshwater and estuarine environments within the Fraser Basin have been directly altered by human activities which have resulted in losses of salmonid production (Tutty, 1976; Birtwell et al., 1988; Northcote and Burwash, 1991). Some examples of these human related large scale alterations include railway construction at Hell's Gate, dam construction on the Nechako, Bridge-Seton, Stave, Alouette, and Coquitlam rivers, logging effects on Nadina River and Weaver Creek, and dyking and draining of a large component of Sumas Lake.

Examples of small scale impacts on salmonid production and other fish stocks also occur throughout the Fraser Basin primarily in the form of incremental encroachment of human development. Specifically, continual urban and agricultural encroachment often produce undesirable fish habitat alterations over the long-term and even over a short-term period. However, unlike large scale impacts on fish production, small scale impacts are often less obvious to humans and are much more difficult to assess. It is suggested that the primary risk to sustained fish production in the Fraser Basin is the cumulative effect of these small scale habitat alterations which have direct negative impacts on fish production (Fleming et al., 1987; Servizi, 1989; Northcote and Burwash, 1991).

Management of the Fraser River fish stocks in the face of this gradual encroachment of human development requires careful maintenance of fish habitat and planning of land and water use within the basin. In order to do this, we need to investigate more fully the quantitative relationships between land and water resource use and fish habitat quality and quantity. It is not until we understand these relationships that we can rationally make better land and water use decisions that are compatible with "sustainable" production of salmonids and other fish stocks in the Fraser Basin. To date no structured plan exists that maps out the long term strategies necessary to comprehensively manage fish habitat in conjunction with associated land and water use.

Although many non-salmonid fishes utilize the Fraser River Basin and its tributaries to carry out their life processes, this paper will primarily focus on salmonids and their habitat requirements because of their important commercial, recreational, and Native Indian food fishery values. It should be stressed, however, that many of the biological, physical, and chemical characteristics that influence salmonids are also important to non-salmonids.

1.1 Goal

The goal of this study is to identify relationships between important characteristics of fish habitat and land use in the Salmon River watershed using Geographic Information System (GIS) techniques. Baseline information on fish habitat and land use will be useful in the development of long-term strategies to manage fish habitat in conjunction with associated land and water use.

1.2 Objectives

1. To compare the distribution of land use within the Salmon River basin among categories of overall land use conditions, a 500 meter buffer around the stream network, and 500 meter buffer segments around critical fish habitat reaches.

2. To quantify temporal changes in land use within the basin over a 10 year period (from 1979-80 to 1989-90), again comparing overall watershed conditions, a 500 meter buffer around the stream network, and 500 meter buffer segments around critical fish habitat reaches.

3. To identify critical fish habitat areas (spawning and nursery rearing sites) that fish use (specifically salmonids) and to characterize any physical features that have changed over a 10 year period from 1980 to 1990.

4. To describe possible relationships and trends between fish habitat and stream-side land use.

CHAPTER 2

BACKGROUND

2.1 Sustainability of Salmonid Fish Resources in the Fraser Basin

The Fraser River Basin (Figure 1) has seen some dramatic changes over the last few hundred years in terms of its natural environment. The increasing demands on the natural resource base together with pressures of settlement and development will continue to put more stress on the basin's natural environment. Today, many groups and individuals are voicing concern about the future of the many components that make up the Fraser River Basin including the salmonid fishes. The nature and scale of human activity is receiving greater attention with respect to the sustainability of development (Dorcey, 1991).

Before describing some aspects of sustainability of salmonid fish resources in the Fraser Basin, a better explanation of the word "sustainability" with respect to fish resources is needed. From the perspective of the Department of Fisheries and Oceans (DFO), an agency responsible for the conservation and management of Fraser River Salmon, a fishery is sustainable if the average annual harvest does not lead to the long-term, continuous decline in abundance of the stock that is the target of the harvest. This particular definition of sustainable development, even in a fisheries context, is quite narrow in focus. Ultimately, if we are concerned about the long-term sustainability of salmonid fish resources in the

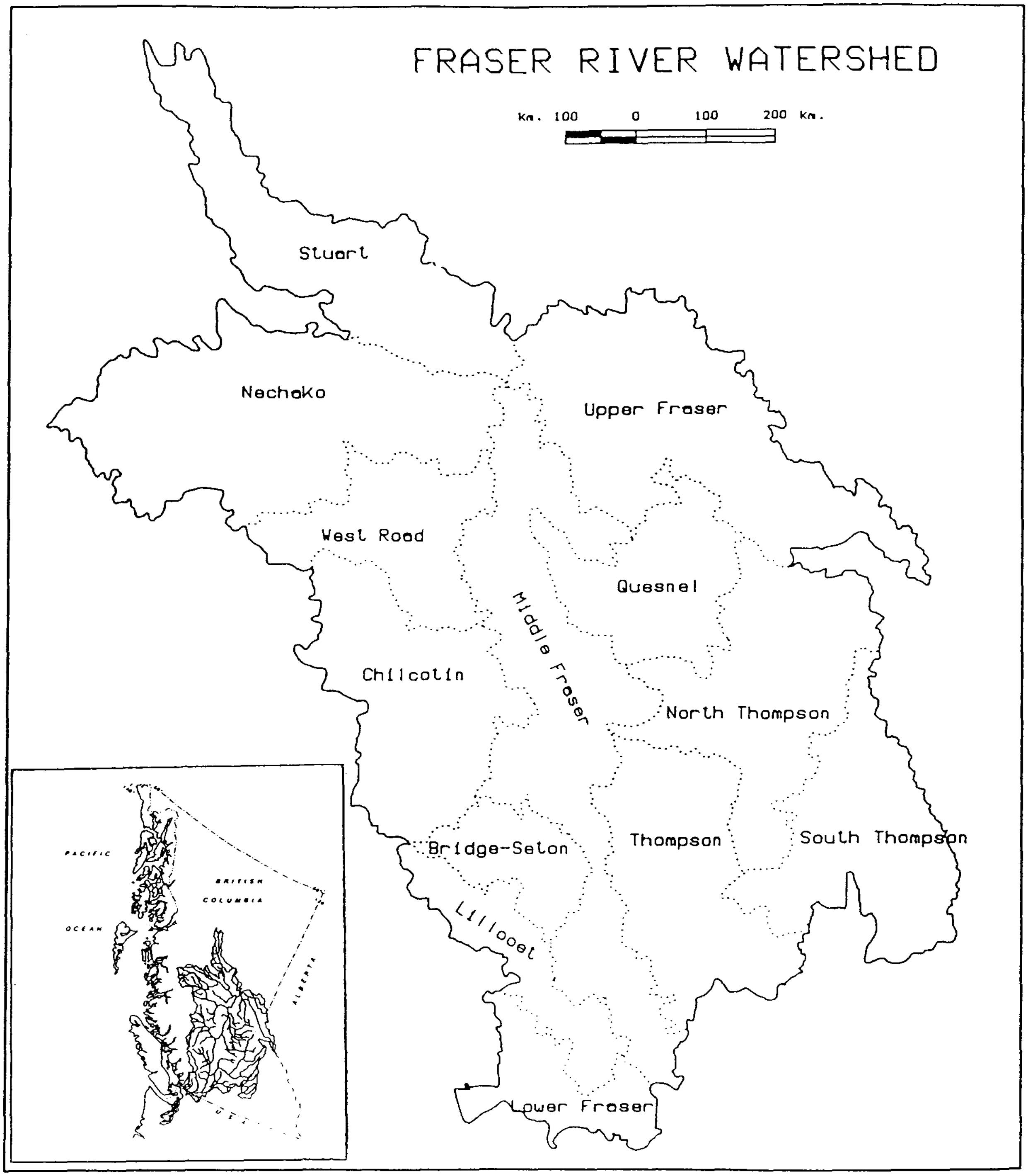


Figure 1. The Fraser River watershed and boundaries of its 13 sub-basins.

Fraser Basin, definitions of sustainability will have to be expanded. Henderson (1991) states that the process through which an expanded definition is developed will of necessity have to involve all those who use or affect, directly of indirectly, the water resources of the Fraser River Basin. A definition should not only represent production and biological aspects of salmonids, but also incorporate a wide range of human social interactions. Toward this end, DFO has recently established the "Fraser River Environmentally Sustainable Development Task Force" that is devoted to exploring sustainable development concepts in relation to the Fraser River Basin.

Due to its size, age, and importance as the greatest salmonid producer in the world (Northcote and Larkin, 1989), the Fraser River Basin provides an excellent system in which to examine and test possibilities for sustainable development (Northcote and Burwash, 1991). The Westwater Research Centre has recently published two books relevant to this topic which focus on water resources and the way in which they might be managed under a policy of sustainable development (Dorcey, 1991; Dorcey and Griggs, 1991).

The dramatic increase of human population growth rates is of obvious concern to the sustainability of salmonid fish resources in the Fraser Basin. Based on the 1986 census, British Columbia had a population of 2.9 million people, of which approximately 63% live in the Fraser River Basin (Table 1). The population distribution in the Fraser Basin can be described in three ways: acute urban concentration, small rural populated areas, and vast regions of relatively uninhabited lands. The Fraser Basin is probably the most contrasting example of population concentration of any major river system in the temperate regions of the world (Schreier, et al. 1991).

Table 1. Fraser River Basin population distribution and density by Sub-basin (1986). (Adapted from Boeckh, et al. 1991).

Sub-basin	Total Population	% of Total Fraser Basin	Area (ha)	People per ha
Upper Fraser	5,585	0	2,818,650	0.0020
Stuart	6,564	0	2,021,700	0.0032
Nechako	19,534	1	3,131,250	0.0062
West Road	479	0	1,251,150	0.0004
Quesnel	9,566	1	1,231,050	0.0078
Chilcotin	2,115	0	1,963,950	0.0011
Bridge-Seton	3,872	0	659,550	0.0059
Middle Fraser	114,594	6	2,988,150	0.0383
North Thompson	16,062	1	2,067,600	0.0078
South Thompson	40,871	2	1,718,100	0.0238
Thompson	80,762	4	1,781,400	0.0453
Lillooet	2,218	0	814,950	0.0027
Lower Fraser	**1,526,359**	**83**	**713,100**	**2.1405**
Total	1,828,581	100	23,160,600	0.0790
(GVRD)	(1,262,387)	(69)	(260,360)	(4.8486)

Most of the people living in the basin (approximately 1.8 million) reside in the Lower Fraser Sub-basin west of Hope. Statistics Canada (1988) documented that between 1981 and 1986 the Lower Fraser Basin had one of the fastest growth rates in the country (9.1%). Furthermore, the population growth rate is expected to stay high due to the region's attractive climate, landscape, recreation interests, and economic opportunities. If population growths continue at this rate, the amount and concentration of various human activities will also increase.

One of the most important threats to the sustainability of salmonid fish resources in the Fraser Basin is the effect of habitat alterations caused by various human activities. Dyking and filling of the Fraser River estuaries and wetlands to promote alternative land uses, log boom storage on the North Arm of the Fraser, dredging of the river bottom to benefit shipping routes, and removal of large woody debris in small "urban" streams are just a few examples of physical activities which can lead to potential habitat problems. Several recent papers deal wholly or in part with salmonid fish habitat issues related to human impacts in the Fraser Basin (see Tutty, 1976; Levy and Northcote, 1982; Birtwell et al., 1988; Servizi, 1989; Northcote and Larkin, 1989; Henderson, 1991; and Fausch and Northcote, 1992).

Water quality is also an important parameter of salmonid fish habitat. Evidence of mercury contamination in trout, char, and whitefish was found in Pinchi Lake in the Stuart Sub-basin where cinnabar deposits (mercury sulphide ore) were mined and tailings discharged to the lake (Peterson, et al., 1971). Many of these fish were below the acceptable standards for fish consumption (Northcote et al., 1975). In addition, recent studies have revealed high levels of dioxin and other organochlorines in juvenile chinook salmon exposed to pulp mill effluent in the Upper Fraser River (Rodgers et al., 1989).

In general, there are vast complex problems associated with recent salmonid fish habitat changes within the Fraser River Basin, many of which can be directly attributed to human activities as a result of increased population pressures. Some habitat management improvement measures (e.g. DFO's policy pertaining to "no net loss" of fish habitat) have been relatively successful, however, new approaches need to be developed to arrive at better sustainable scenarios for salmonid fish resources. Protection of spawning and rearing areas within the Fraser River Basin and identifying factors that control the freshwater environment are necessary (Henderson, 1991). For the most part, descriptions of spawning and juvenile rearing areas are reasonably complete for all major Fraser River salmonid stocks. However, Henderson (1991) suggests that there is little information pertaining to spawning and rearing sites for the smaller Pacific salmon stocks, particularly small coho salmon stocks. It can be said that a disproportionate amount of the genetic stock of a species, and consequently the ability to survive in a changing environment, is contained within these smaller populations (Scudder, 1989).

This paper examines the Salmon River, a small watershed in the municipality of Langley which is presently being subjected to increased human activities brought about by population pressures. This sub-basin is also an important spawning and rearing area for a small but important population of coho salmon and other salmonids.

2.2 The Salmon River Watershed: A Case Study

Visualizing a "sustainable" fisheries resource in the Fraser Basin is difficult because of the basin's large geographic area and the complex interactions that take place between the human components and the natural system. An attempt to establish more "sustainable" methods of fish management in a smaller geographic area like the Salmon River watershed may be more desirable in developing and understanding "sustainable" processes, although even areas of this size have extremely complex interactions when information is processed at an appropriate scale.

The likely development pattern for the Salmon River watershed reveals that increased population growth along with residential land development will be the key issue for fisheries management as urban development moves into rural areas. This trend of human encroachment is quite evident in the Lower Fraser sub-basin as one views False Creek, Musqueam Creek, Capilano River, the North Shore watersheds, Brunette River, Coquitlam River, Nicomekl River, Serpentine River, and now other watersheds that continue east up into the Fraser Basin. Paish (1981) commented that settlement in the Lower Fraser sub-basin shows that the Salmon River is simply on the "leading edge", and that problems that have led to the loss of so much fish habitat to the west are already occurring within the basin's municipal boundaries. Reports prepared for the Salmonid Enhancement Program by Paish (1981) recommend more research in order to strengthen the scientific basis for a cooperative watershed planning and management system in the Salmon River watershed. Paish (1981) also notes that the Salmon River is as important to the understanding of urban/rural fringe watersheds as Carnation Creek is to forested watersheds.

The Salmon River watershed presents a good case for evaluating relationships between land use and fish habitat for several reasons. First, the Salmon River is one of the most productive systems (for its size) for coho salmon and other salmonids (i.e. steelhead and cutthroat trout) in the Fraser Basin. Recent escapements of Salmon River coho are about 4% of the Fraser River total (Farwell et al., 1987). The physical features that are in the middle reaches of the Salmon River and its main tributary Coghlan Creek, provide excellent spawning and rearing habitat for salmonids. Second, the rate of land use change from agricultural and undeveloped lands to urban areas has been high in the last few decades and continues to increase. The basin is therefore appropriate for identifying trends of incremental small scale human development in relation to salmonid habitat. Finally, if linkages between important characteristics of fish habitat and land use can be made, a basic framework from which to comprehensively manage fish habitat in conjunction with land and water use can be generated.

2.3 Government Agencies, Interest Groups, and Public Involvement in the Salmon River Watershed

If we want to comprehensively manage fish habitat in conjunction with land and water use, planning should involve all relevant stakeholders. Some of the major government and non-government groups that have a key role in managing the fisheries resource and land and water resources in the Salmon River watershed include the federal Department of Fisheries and Oceans (DFO), the provincial Ministry of Environment, Lands and Parks (MOELP), the Municipality of Langley, several conservation groups, and the general public.

The Department of Fisheries and Oceans is responsible for administering the Fisheries Act which directs the agency to protect fish and fish habitat in "waters frequented by fish" (Chilibeck et al., 1992). The habitat management framework outlined in the Fisheries Act is specifically the responsibility of the Habitat Protection Division. The act itself defines fish habitat to include spawning grounds, nursery and juvenile rearing grounds, and food supply and migration areas on which fish depend, directly or indirectly, in order to carry out their life processes. The federal Department of Environment plays a supportive role with regard to the regulation of water pollutants.

At the provincial level, the Fisheries Branch under MOELP manages steelhead and cutthroat trout. Provincial management activities are directed by the federal Fisheries Act and the provincial Wildlife Act which are applied mainly to recreational fishing activities. The Fisheries Branch, under the Fisheries Act, is responsible for assessing and managing freshwater fish stocks and their habitat. In realistic terms, this means the province has a shared responsibility for overall salmonid habitat protection with DFO. The implementation of water management activities including floodplain management, watershed protection, and water licensing, is also a provincial responsibility under the Water Management Branch.

The Langley Municipal Government is primarily responsible for regulating land development within its jurisdiction. Moreover, the municipality reviews and authorizes development applications for eight communities within its municipal boundaries. Many of the development applications (mostly urban proposals) within the Salmon River watershed occur in the communities of Salmon River Uplands and Fort Langley. Due to the increase in urban development beginning in the late 1970's, the municipality began to participate in the fisheries referral process in 1980. As well, in 1980 the Langley council endorsed the principle of "cooperative watershed management" as proposed by Paish (1980), which addressed issues of maintaining and improving salmonid production through the cooperative planning and management of watersheds.

In addition to the various government agencies that conduct management activities within the Salmon River watershed, there are a few non-government organizations that have direct input as well. For example, the British Columbia Conservation Foundation, a non-profit society located within Langley Municipality, has been involved in many fish habitat restoration programs, stream-side protection and stabilization programs, clean-up projects, and storm drain marking programs. Also, public initiatives such as the West Creek citizens group have conducted literature reviews on water quality, vegetation, and other natural resource issues in the watershed. Some members of the West Creek group now sit on an environmental committee and make recommendations to the municipal council on a variety of environmental issues.

With respect to public involvement, individuals who live in the watershed do not formally participate in the decision-making process. However, most of the land base within the watershed and particularly the stream-side land base, is under private ownership. Under these circumstances, it seems logical that cooperation with individual property owners is essential for managing the fisheries resource in conjunction with land and water use. Even people who do not own stream-side property but still live within the watershed and beyond, should be involved to some degree in decision-making. In general, people like salmonids! The public equates healthy populations of salmonids in "their stream" to a healthy aquatic environment. Most of the people that live in the Salmon River watershed decided to make it their home because of the unique natural features (including the presence of salmon and trout) that the area provides (Paish, 1981).

2.4 Geographic Information Systems (GIS)

2.4.1 Important Aspects of GIS

Geographic Information Systems (GIS) are an integrated set of hardware and software tools for the collection, maintenance, analysis and display of geographically referenced data. Geographical data describe objects in terms of their position relative to a known coordinate system, their non-spatial attributes, and their topological and spatial interrelations. Data can be accessed, transformed, and manipulated interactively, facilitating thematic mapping, inventory, updating, multidisciplinary surveys and maps for specific and multi-user needs (Starr and Estes, 1990; Arnoff, 1989; Burrough, 1986).

Geographic Information Systems use both spatial and non-spatial forms of data. Spatial data represent points, lines, and polygons (e.g. hydrometric stations, streams, and land use polygons, respectively) while non-spatial data are descriptive attributes associated with spatial features (e.g. stream discharge and fish habitat characteristics).

Data may be graphically represented within a GIS in either raster or vector formats. Raster data structures consist of an array of grid cells referenced by coordinates and independently addressed with the value of an attribute. Information is standardized to one resolution based on the grid size. Vector data structures position point data by an x,y coordinate pair. Lines consist of a beginning point, an end point and a series of line segments. Unlike raster data structures which have problems of precision associated with grid cell size, vector formats define position, length, and dimensions of spatial data corresponding to the accuracy and precision reflected in the source map base.

2.4.2 The Use of GIS to Evaluate Fish Habitat and Land Use

The use of GIS has become accepted in the mainstream of management systems, and is now becoming recognized as a helpful tool in fisheries management. In 1985, DFO released a federal policy document on fish habitat management consisting of nine strategies. Four of nine management strategies are closely linked to the use of GIS in managing fish habitat in conjunction with land use as outlined by Collins and Simmons (1986). First, "protection and compliance" requires evaluation of habitat in relation to development initiatives. Second, "consultative resource planning", necessitates assimilation of large amounts of spatial and non-spatial data from numerous sources. Third, "scientific research" necessary to improve the quality and quantity of habitat information can benefit from the analytical capabilities of GIS. Fourth, "habitat monitoring" is more readily accomplished by the storage and updating capacity of GIS.

There are only a few examples available where GIS has been used in relation to fisheries and land use issues. Dick (1989) developed a cartographic model for riparian buffers using GIS to process site specific data that influence stream temperature. The goal of the study was to recommend riparian designs that would maintain stream temperatures suitable for fish. Collins and Simmons (1986) used GIS concepts and applications to formulate a demonstration project on the Nepisiquit River in northern New Brunswick. The project illustrated how GIS could be used to describe salmon habitat and facilitate the review process for development approvals.

Although there are limited examples of GIS projects related specifically to fish habitat and land use, the widespread acceptance of GIS technology in other resource-related disciplines is growing rapidly.

CHAPTER 3

STUDY AREA

The Salmon River watershed is located east of Vancouver, British Columbia in Langley Municipality within the lower Fraser Basin (Figure 2). A small portion of the upper region of the watershed occupies land in Matsqui Municipality. The watershed has an area of approximately 8070 ha and has an elevation range of 2 to 137 meters (1:25,000 NTS map sheet). The Salmon River itself flows in a northwesterly direction for 33 km and enters the Fraser River immediately west of Fort Langley. Coghlan Creek (Figure 3), the principal tributary, joins the mainstem approximately 14 km upstream from the Fraser River. The upper reaches of the basin are marshy with low summer flows and have relatively open flat stream bank slopes. In the middle reaches, the river flows across moderate gradient terrain where flow is consistent through summer months due to spring-fed conditions. Stream bank slopes in the middle reaches range from 5 to 40 percent which act to buffer the mainstem and major tributaries. This middle area is particularly valuable to salmonids because of its alternating riffles, glides, pools, and sloughs, its medium sized gravel substrate, and extensive stream-side vegetation. The lower reaches are slow moving with deep channels that meander sharply through floodplain conditions. This lower area primarily acts as a travel corridor for salmonids to access spawning and rearing areas in the middle reaches.

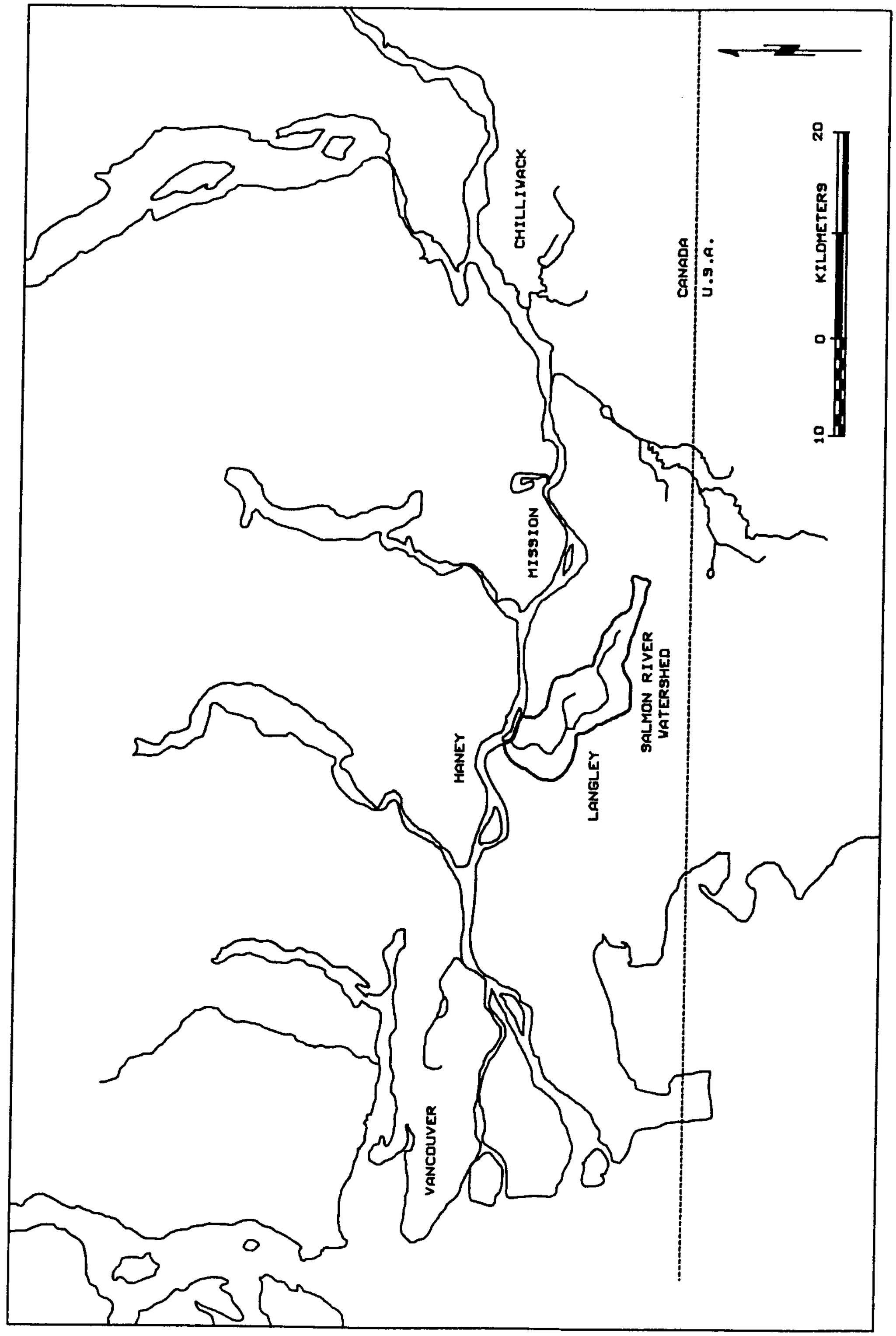


Figure 2. Location of the Salmon River watershed in the Lower Fraser Valley.

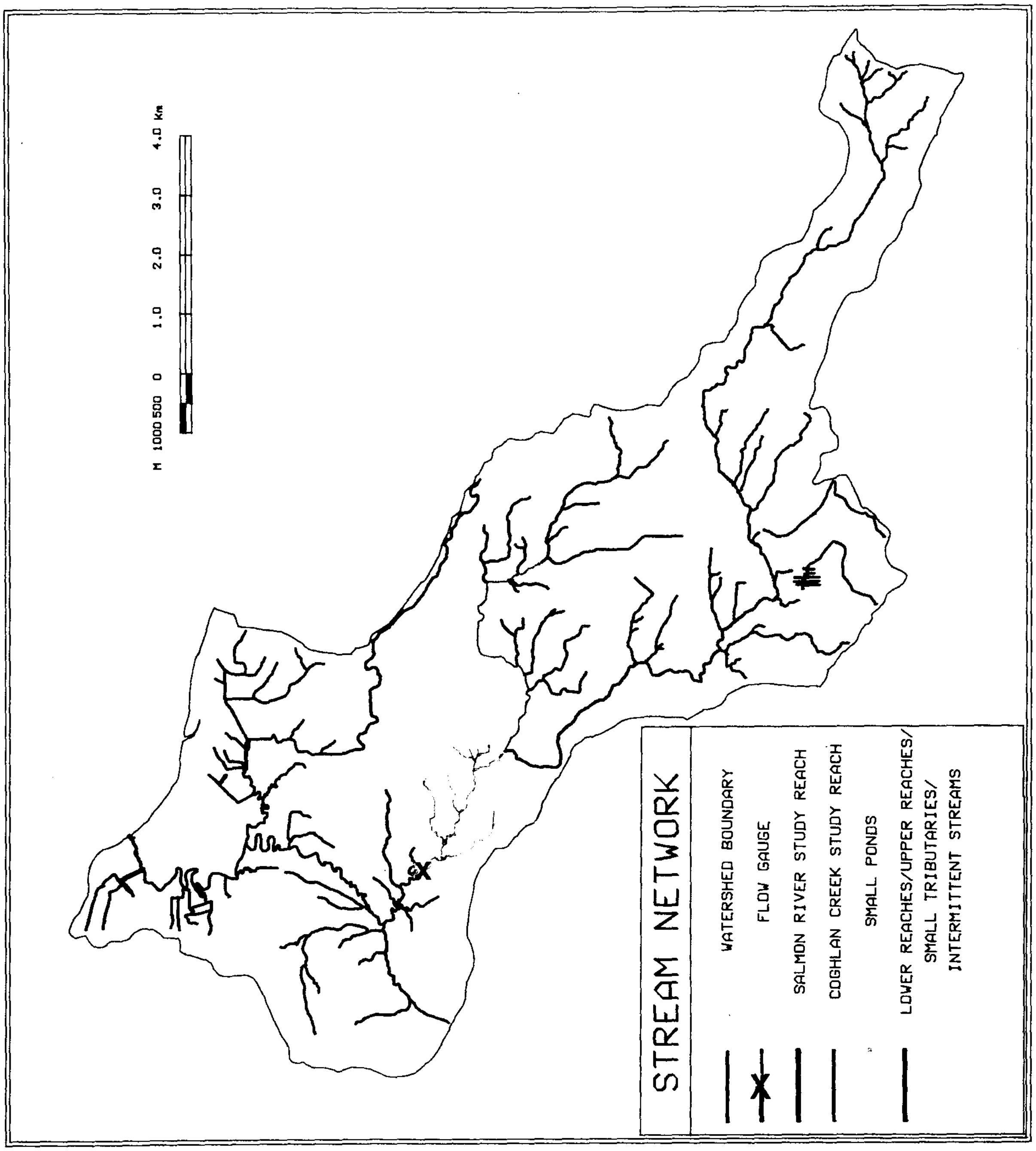


Figure 3. The Salmon River watershed stream network.

3.1 Physical Description

3.1.1 Climate

The major climatic influences on the Salmon River watershed are the Pacific Ocean to the west, the Coast Mountains to the north, and the Cascade Mountains to the east. The closest weather station is located to the south in Langley Prairie . The station records an average rainfall of 1554 mm per year based on a 30 year record (an additional 74 mm falls as snow). December is the wettest month with an average precipitation of 241 mm. The driest months occur between July and early September. Rainfall during this period averages only 6% of the total annual precipitation. The mean annual air temperature is 9.6 degrees Celsius (Carmelita, et al., 1990). The climatic regime contibutes to the basin's stream flow hydrograph.

3.1.2 Surficial Materials

Eggleston and Lavkulich (1973) divided the Salmon River watershed into geomorphic units based on the origin and texture of surficial materials using the surficial geology information of Armstrong (1957) and the soils information of Luttmerding and Sprout (1966). Based on this information (Figure 4), five major sedimentary units can be distinguished: (i) on the westernmost edge, glacial-marine deposits are dominant (5%); (ii) filling a central, north-south corridor linking Langley and Fort Langley, are marine deposits up to 250 meters thick (19%); (iii) to the east, around the Salmon River/Coghlan Creek confluence, large areas of outwash sands and gravels are present (29.5%);

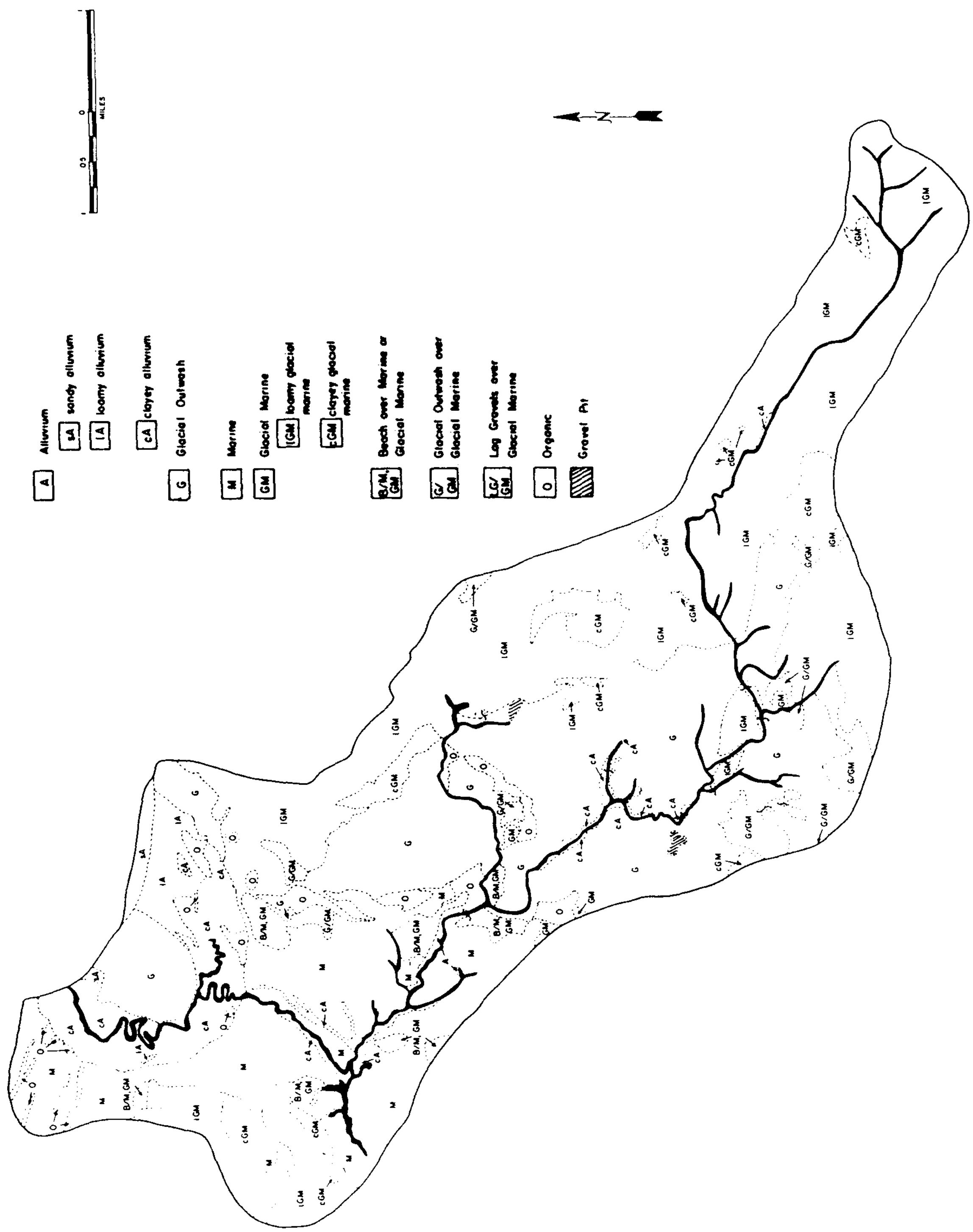


Figure 4. Surficial materials of the Salmon River watershed (Slaymaker and Lavkulich, 1978).

(iv) the easternmost part of the watershed around Aberdeen, is underlain by glacial marine sediments (39%); (v) the final unit underlies the abandoned meander of the Fraser River and is covered with flood plain materials (7.5%) which corresponds to the depression encircling Fort Langley (Slaymaker and Lavkulich, 1978). In a subsequent study to Eggleston and Lavkulich (1973), Slaymaker and Lavkulich (1978) describe the term geomorphic unit as a spatial entity that is homogeneous with respect to surficial materials, slope and drainage. Geomorphic unit maps were used to determine the ability of the land to cope with pollutants attributed to various land uses. These units play an important role in the streamflow regime of the Salmon basin.

3.1.3 Streamflow

Due to the nature of the surficial materials and the relatively high water table in the middle reaches of the watershed, the basin has an unusually "flashy" hydrologic system (personal observation, 1990) for an area with very little overall relief. This is especially evident during intense rainfall events. This rainfall/streamflow response is less obvious in the lower reaches of the basin where the Salmon River is regulated at the Fraser River confluence by a flood gate and pump system that operate during spring freshet.

Gauging of the Salmon River discharge was initiated by Environment Canada, Water Resources Branch, in 1960 and reestablished in 1968. The gauge station (#08MH090) is located on the mainstem of the Salmon River at 72nd avenue crossing (see

Figure 3 - page 20).

Discharge records for the Salmon River station from 1970 to 1990 show that low flow periods generally occur between the months of June and September and high flow periods occur between November and March (Figure 5). The mean monthly discharge and minimum and maximum variations are shown in Figure 6. The lowest minimum daily discharge recorded during this time was 0.099 $m^3 s^{-1}$ on October 1, 1975, and the largest maximum daily discharge was 39.3 $m^3 s^{-1}$ on February 12, 1986. The highest instantaneous discharge (within one day) ever recorded was 64.6 $m^3 s^{-1}$ on December 17, 1979.

Daily discharge records for July, August and September, in 1980 and 1990, are compared in Figure 7. The average discharge over the three month period for 1980 is 0.35 $m^3 s^{-1}$ as compared to 0.25 $m^3 s^{-1}$ for 1990. The 3 months within these two years correspond to fish habitat data collection times described later in this paper.

3.1.4 Water Quality

The water quality in the Salmon River and its tributaries has been identified as a major concern over the last few decades (Grant and Blackhall, 1991; Paish, 1981; Beale, 1976; Hall, et al., 1974; Benedict et al., 1973). Benedict et al. (1973) found that of 17 Lower Fraser tributary streams and rivers, the Salmon River system ranked the lowest overall in terms of 13 water quality parameters during a 1972 summer sampling period. Biochemical oxygen demand, total nitrogen, fecal coliforms, and

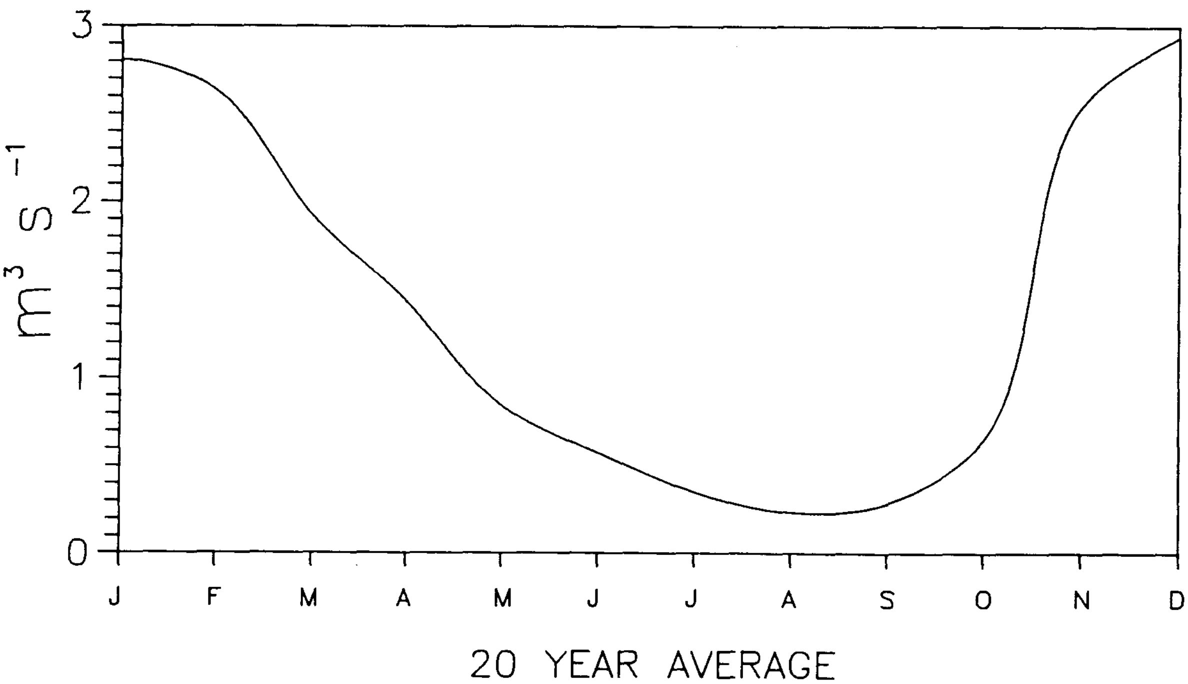


Figure 5. A 20 year hydrograph (1970-1990) of the Salmon River mainstem at 72nd avenue crossing - gauge #08MH090 (Environment Canada, 1991).

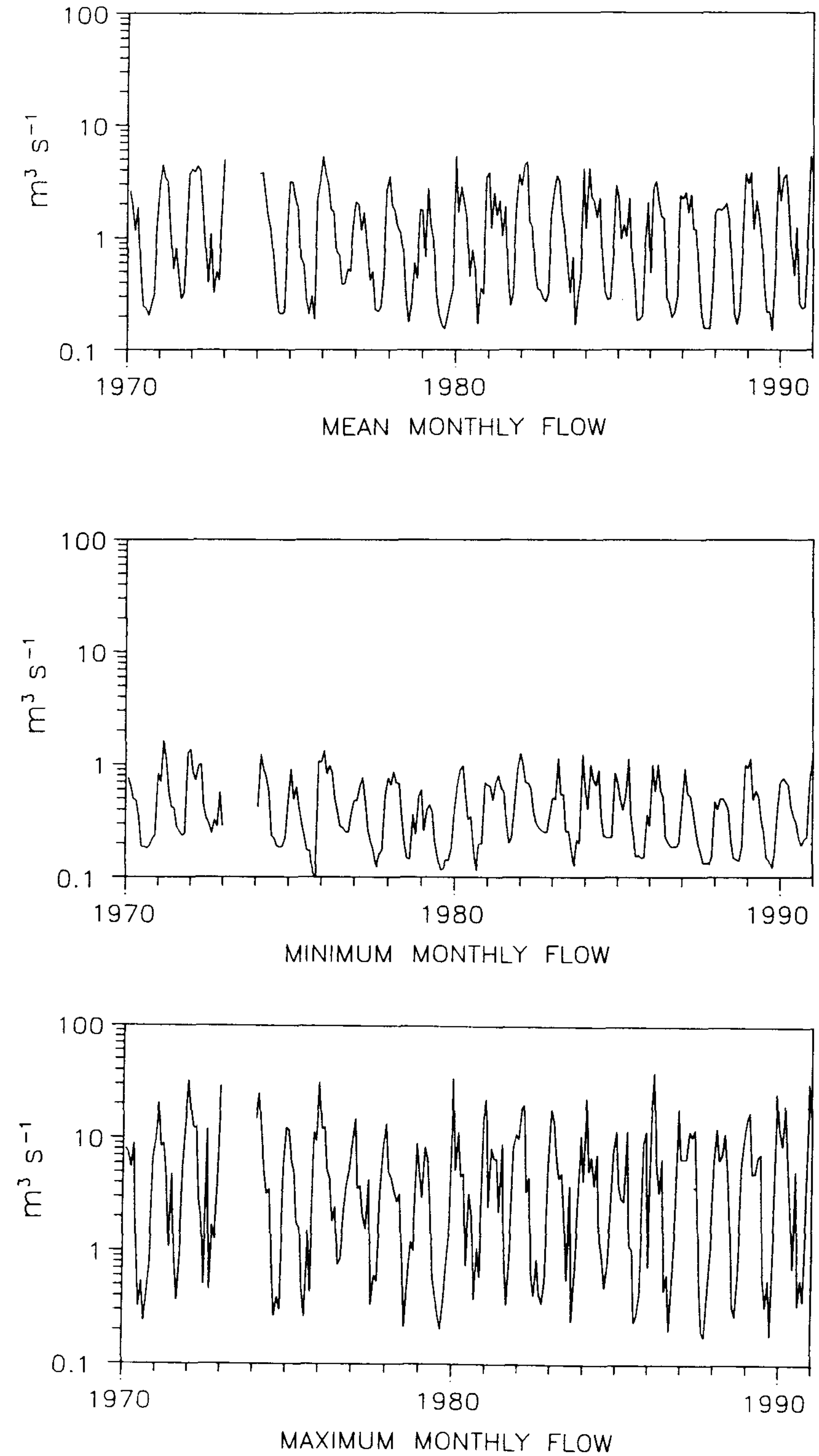


Figure 6. Mean monthly discharge of the Salmon River mainstem with minimum and maximum variations (1970-1990) - gauge station #08MH090 (Environment Canada, 1991).

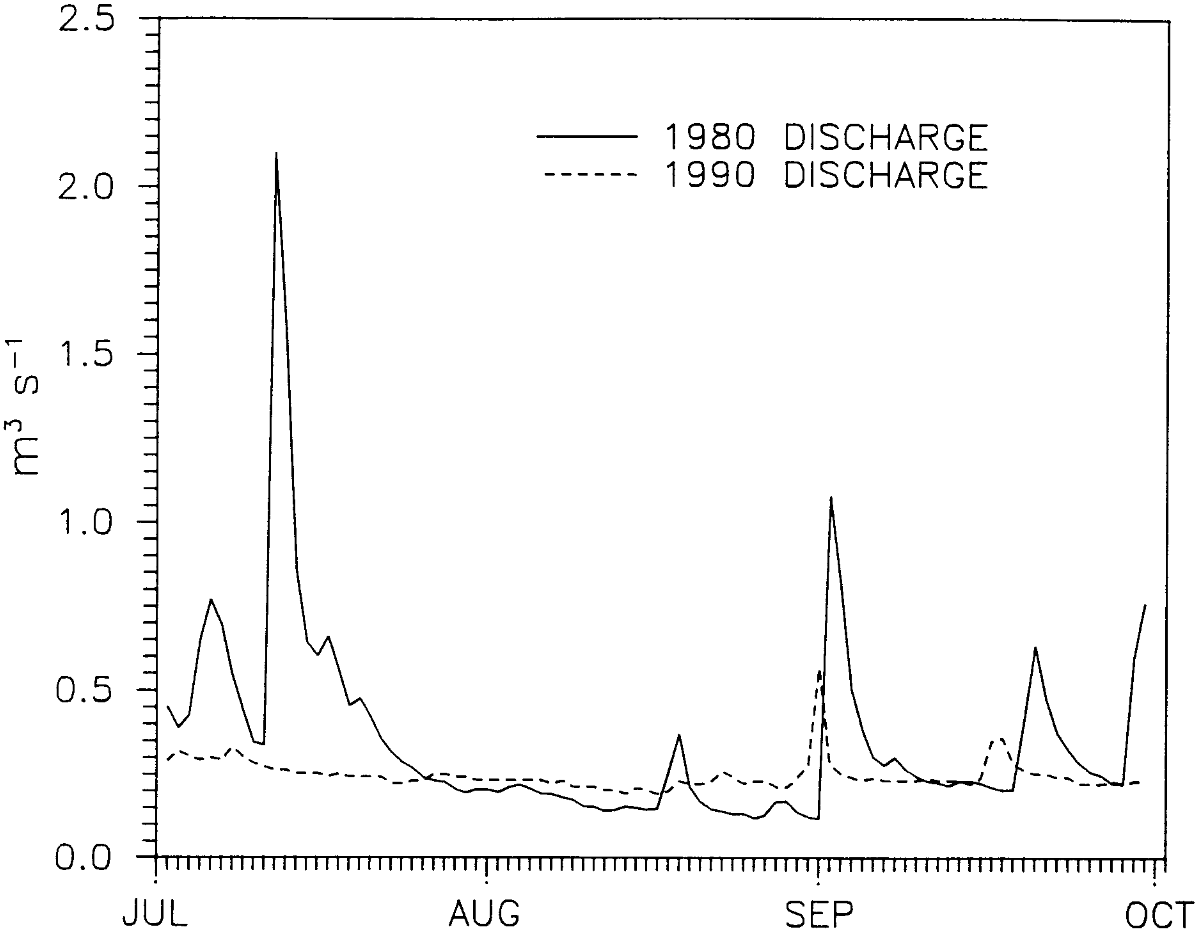


Figure 7. Daily discharge for the Salmon River mainstem during July, August and September in 1980 and 1990 - gauge station #08MH090 (Environment Canada, 1991).

some trace metals were particularly high relative to other streams. High sediment loads in many of the Salmon River tributaries are also a problem according to various sources, although very little quantitative documentation exists. Most of the water quality problems are associated with non-point sources; however, sewage effluent from Trinity Western College is at least one point source of pollution that is of concern.

3.2 Human Population Trends

Langley Township is approximately 75% rural (e.g. dairy farms, crop production, hobby farms) and 25% urban in the designated communities of Aldergrove, Brookswood, Fernridge, Fort Langley, Murrayville, Salmon River, Walnut Grove, Willowbrook and Willoughby. Langley Township and the City of Langley are two separate municipalities, both of which are members of the Greater Vancouver Regional District (GVRD). Of the 18 GVRD municipalities, Langley Township had the second highest increase in population between 1981 and 1986. Population has grown rapidly from 36,000 in 1976 to 63,100 in 1990. Between 1986 and 1990 the average growth rate was over 4% annually. By 2001, the population is expected to be over 90,000 (Langley Community Development Department, 1990).

Approximately 12,000 people live within the Salmon River watershed boundary, mainly in the Fort Langley and Salmon River Uplands communities. These two communities have experienced population growths of 4% and 11% respectively from 1986 to 1990. By 2001, population in the Salmon River Uplands community is expected to be close to 7,000. In addition, housing contracts in this community increased by 11.8% from 1,519 in 1986 to 1,698 in 1990 (Langley Community Development Department, 1990). The Salmon River Uplands community is located in the middle reaches of the watershed.

3.3 Fish Resources

3.3.1 Fish Populations

At least 15 different species of fish utilize the Salmon River and its tributaries to carry out at least part of their life cycle (Table 2). In particular, the Salmon River is a highly productive system for coho salmon and steelhead and cutthroat trout. The following is a brief summary of research conducted on salmonid fishes in the Salmon River watershed.

Table 2. Sampled species of fish in the Salmon River Watershed (adapted from Hartman, 1968; supplemented from McPhail, 1992).

Species	Common Name
Oncorhynchus kisutch	Coho salmon
Oncorhynchus mykiss	Steelhead trout
Oncorhynchus clarki clarki	Cutthroat trout
Cottus asper	Prickly sculpin
Catostomus macrocheilus	Largescale sucker
Catostomus sp.	Salish sucker
Ameiurus nebulosus	Brown bullhead
Ptycocheilus oregonensis	Northern squawfish
Cyprinus carpio	Carp
Mylocheilus caurinus	Peamouth chub
Richardsonius balteatus	Redside shiner
Hybognathus hankinsoni	Brassy minnow
Gasterosteus aculeatus	Threespine stickleback
Lampetra tridentata	Pacific lamprey
Lampetra richardsoni	Western brook lamprey

General descriptions of growth, life history and distributions of Salmon River coho salmon, steelhead and cutthroat trout are provided by McMynn and Vernon (1954), Hartman (1965), Hartman and Gill (1968), and Hartman (1968). Annual adult coho salmon escapements have been estimated for the Salmon River watershed from 1951 to the present (Farwell et al. 1987; Schubert and Kalnin, 1990; Schubert, 1991.) (Table 3). Since collection efforts and techniques for obtaining escapement figures have varied substantially since 1951, the data is inconsistant and comparisons are difficult (Schubert, 1991). Peterson mark-recapture methods were used to calculate escapement from 1986 to 1990.

Table 3. Annual coho salmon escapements to the Salmon River watershed averaged every 10 years from 1951 to 1980, and averaged every 5 years from 1981 to 1990 (Farwell, 1987; Schubert and Kalnin, 1990; Schubert, 1991).

Year	Escapements (Avg)
1951-1960	888
1961-1970	293
1971-1980	3227
1981-1985	2161
1986-1990	7550

The abundance of juvenile salmonids and estimates of returns by adults have been determined for several years in the late 1970's and in the 1980's. Electroshocking surveys of juvenile coho salmon, steelhead and cutthroat trout in particular reaches of the Salmon River, and its tributary, Coghlan Creek, were conducted in 1979, 1980, and 1981 (see DeLeeuw 1982 for results and DeLeeuw 1981 for methods). Fence traps, described by Schubert (1982), have been used to count coho salmon and trout smolts in 1979 and 1980 during migration periods (March to June). Coded wire tagging of coho salmon smolts during this time was also done to estimate the proportion of smolts that return as adults and to determine the contribution of Salmon River coho to the tidal fisheries. Additional years of study were conducted from 1986 to 1990 (Schubert and Kalnin, 1990; Schubert, 1991).

3.3.2 Spawning and Rearing Habitat

Only a few salmonid habitat surveys have been conducted in the Salmon River watershed. McMynn and Vernon (1954) present a general description of stream morphology, discharge and stream temperature for most areas in the watershed. This work was initiated because local opinion suggested that high irrigation demands, especially during low flow periods, were jeopardizing salmon and trout populations. In 1972, Erickson and Harding submitted habitat information on a Ministry of Environment stream survey form. A map (scale: 1 inch = 1 mile) was produced that divided the basin into suitable, potential and marginal fish habitat based on substrate analysis, stream-side vegetation and instream cover. The last and substantially more quantitative habitat inventory was completed by DeLeeuw (1982) based on field work done in 1979, 1980 and 1981 during low flow conditions. Part of the impetus for this work was to determine if a major flood event which occurred in the winter of 1979 had a substantial impact on stream habitat and salmonid populations. The study concluded that only surface substrate conditions had been altered. DeLeeuw's habitat inventory included detailed stream morphology, substrate analysis and instream and overstream cover of the Salmon River and Coghlan Creek basins.

3.4 Land Use Issues and Impacts on Salmonid Fish Habitat

3.4.1 Historic and Present Land Use Trends

With the exception of the flood plain located in the Fort Langley area, the entire Salmon River drainage was originally covered by a dense coniferous forest. The area was logged and later replaced by secondary growth, primarily Douglas fir and Western hemlock. Agricultural use of the land first began in the latter part of the 19th century when homesteads were established near the confluence of the Salmon and Fraser Rivers. Early clearing and settlement first took place in the upper and lower regions of the basin, where the more productive soils are found. The middle regions of the basin, having more porous soils, were later cleared and replaced by cultivated crops (McMynn and Vernon, 1954). McMynn and Vernon (1954) reported that the removal of forest cover in this middle region seemed to increase the rate of percolation and produced higher stream discharges during periods of heavy precipitation. The increased percolation rate also resulted in lower reserves of ground water during the arid months. Farmers with wells in this area reported a five to seven meter drop in the water table during the summer. Minimum summer discharge also decreased with the removal of forest cover.

From the 1950's through to the late 1970's, the Salmon River watershed was generally classed as an agricultural region. However, from the late 1970's to the present, urban related land use has been increasing at a high rate. Presently, the two principle land uses in the watershed are agriculture and residential development.

3.4.2 Agricultural and Urban Land Use Impacts on Salmonid Fish Habitat

Agricultural and residential land uses in the Salmon River watershed can have both direct and indirect influences on the quality and quantity of fish habitat that can ultimately limit fish production. Low summer flows, diminishing water quality and stream bank erosion are just a few of the issues that have been documented as management problems.

With respect to agricultural practices, Paish (1980) notes that large scale withdrawal of water from the river can theoretically remove half of the low summer flow for much of the system. The middle reaches of the Salmon River mainstem and the lower reaches of Coghlan Creek, recognized as prime salmonid spawning and rearing areas, are particularly susceptible because of the high number of water licenses in the area (aprox. 90

licenses - unpublished data from MOELP). Low summer flows can increase temperatures, decrease oxygen levels, reduce benthic invertebrate populations, increase predation, and decrease the amount of available cover to fish (McMynn and Vernon, 1954; Hamilton and Buell, 1976; Toews and Brownlee, 1981).

A significant proportion of the water quality problems in the watershed are associated with the use of commercial fertilizers, pesticides and herbicides on agricultural crops (Grant and Blackhall, 1991; Paish, 1981). Beale (1976) conducted a study on the effects of land use and soils on the water quality of the watershed and found that pH, temperature, phosphate-phosphorus, iron, copper and manganese exceeded published water quality criteria for drinking water. The report indicated that some agricultural field crops in the study area could be linked to these variables, although geologic materials, residential land use and schools, were also factors. High density production of poultry, swine and other livestock have also contributed to water quality problems in the form of nitrates and fecal coliforms (Paish, 1980; Paish 1981; Beale, 1976; Grant and Blackhall, 1991).

The concentration of domestic stock in and near streams leads to bank breakdown and is one of the most detrimental influences in the watershed (Paish, 1980). High sediment loads from unstable stream banks can have serious consequences on downstream spawning grounds and juvenile rearing sites.

The primary effect of residential development in the watershed is the change it brings about in the natural surface cover of the catchment area under which natural fish populations and the habitat that supports them have evolved. Replacement of vegetation and soil by concrete and asphalt has and will continue to change the moisture retention capability of the watershed and will increase contaminant runoff into streams. Increased storm water runoff collected from paved parking lots, rooftops, roadways, golf courses and residential lawns, can quickly transport heavy metals, road salts, oil products, soaps and detergents, fertilizers, and numerous other contaminants into the streams and creeks (Grant and Blackhall, 1991).

In concentrated residential areas and municipal parks, particularly in the middle regions of the watershed, riparian zones along the streams have been thinned out (pers. observ. 1990). These riparian areas are the sources of instream vegetation and woody debris that form important components of physical fish habitat. Deforestation of riparian areas and direct removal of large woody debris (LWD) from streams is common in many urban watersheds. Fausch and Northcote (1992) comment that standing dead trees are often removed due to the perceived hazard to human life and property, and fallen debris is removed for firewood or "cleaned up" for misguided aesthetic reasons. Fausch and Northcote (1992) studied a small coastal stream and found that stream reaches that had been "cleaned" of LWD had less instream complexity and fewer salmonids present than stream reaches that were relatively untouched.

3.4.3 Barriers to Fish Migration

A flood gate and numerous culverts in the Salmon River watershed are two of the most obvious forms of barriers that either prevent or hinder upstream and downstream migration of salmonid fishes and impact fish habitat.

The flood gate, located at the mouth of the Salmon River, was built and installed between a series of dykes in 1949. This structure prevents Fraser River water from flooding agricultural and residential areas in floodplain regions of the watershed during spring freshet. During this time, the flood gates are closed and water from the Salmon River is pumped over the dyke. In most years, pumping periods extend from late March to July, although the pumps operate automatically at any time when Fraser River water levels are high. The flood gate is maintained and operated by Langley Municipality.

Unfortunately, spring pumping periods coincide with the downstream migration of Salmon River coho salmon and trout smolts. Estimated mortality rates of smolts that pass through these pumps range anywhere from 20 to 40 percent (Schubert, 1991; Schubert and Kalnin, 1990; Paish, 1981;). Other estimates of smolt mortality are as high as 90 percent (Carmelita, 1990).

Culverts are used extensively throughout the watershed and pose considerable problems related to fish migration and fish habitat. As more roads are built to service residential areas and other land uses associated with population growth, the number of culverts installed at stream crossings will also increase (Figure 8). Adult salmonids migrating upstream, salmonid smolts migrating downstream, and anadromous and resident fish of all species and sizes can be adversely affected by habitat changes and unfavourable conditions caused by culverts. Some habitat changes caused by culverts include: physical disturbance of instream cover and stream banks during culvert installation; scouring of stream banks upstream and downstream of culverts producing high sediment loads and habitat alterations; and changes in stream hydraulics which can reduce refuge habitat for fish. Other unfavourable conditions caused by culverts include increased stream velocity and waterfalls which act as migration barriers (Toews and Brownlee, 1981). When culverts become barriers, fish are restricted from reaching important feeding, rearing and spawning habitats, and may also be more prone to predation.

A small project conducted by Allsopp et al. (1992) examined the effects of culverts on anadromous fish passage in the Salmon River and Coghlan Creek. Specifications of culvert types and data from high and low flow conditions were used to:
i) calculate minimum size requirements of salmonids to pass through culverts by month; ii) make recommendations of minimum water depths required by salmonids to pass through culverts during low flow periods; iii) depict problems related to culvert outlets (eg. waterfalls, high discharge rates, downstream hydraulics); and iv) calculate culvert velocity barriers during specific salmonid migration periods. The study concluded that

four of five culverts on Coghlan Creek and five of eight culverts on the Salmon River are barriers to at least one type of salmonid for at least one month during periods of migration (Figure 8). [The author provided data and consulted on the project].

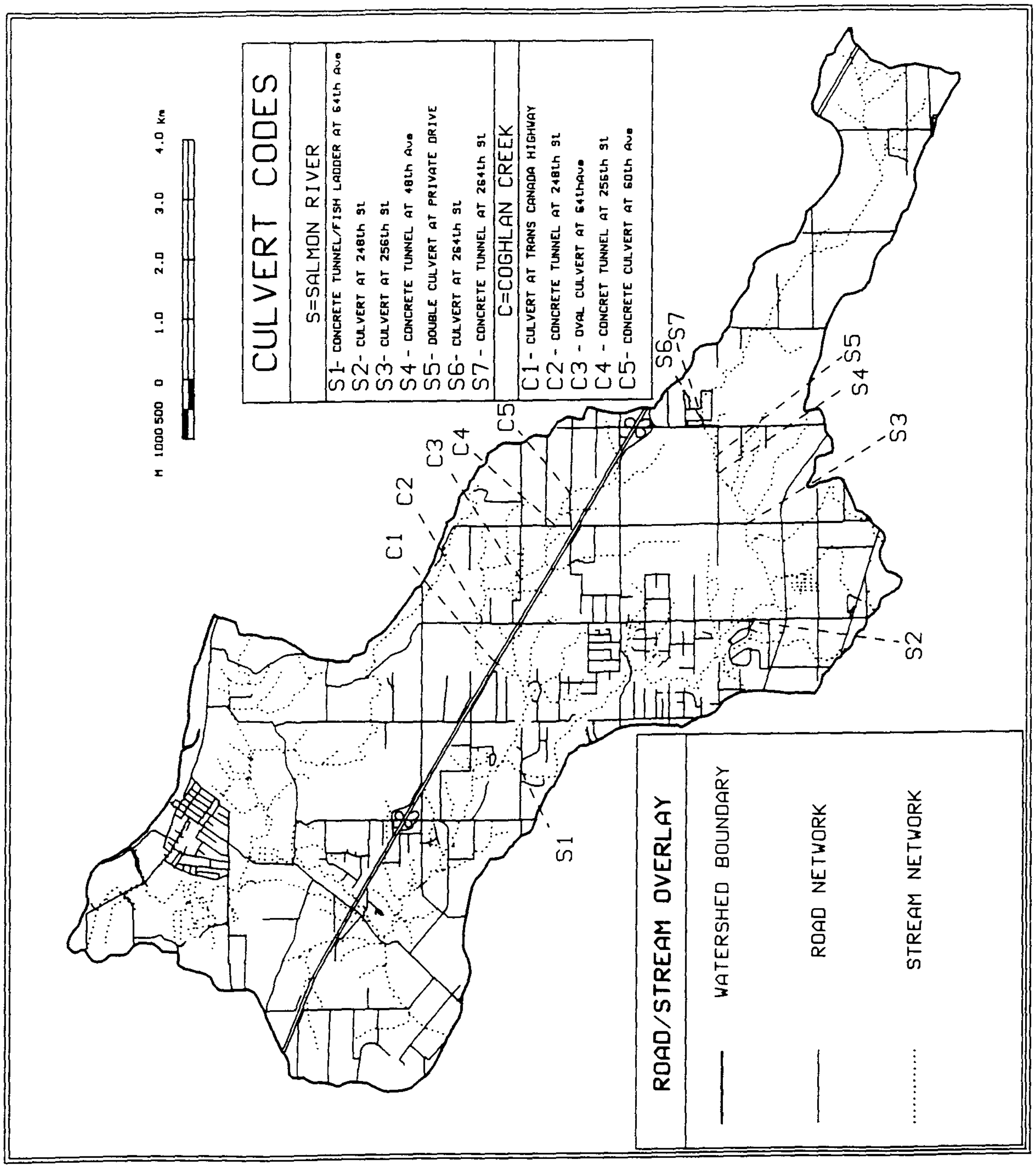


Figure 8. The road and stream network of the Salmon River watershed depicting the major culverts that act as barriers to fish migration.

CHAPTER 4

METHODS

4.1 Evaluation of Land Use Dynamics

Three different types of maps produced from three different sources were used to quantify the spatial distribution and temporal (1979-80 to 1989-90) land use changes in the Salmon River watershed. The next three sections describe these three maps and are followed by two sections that characterize the spatial and temporal aspects of the study.

4.1.1 Base Map

An important step in developing a digital database for any project is to digitize a good quality base map. This map forms the basis upon which information is compiled and determines the ease with which different information sources may be integrated. All points, lines and polygons digitized from various maps are referenced to coordinates defined by the base map.

Four National Topographic 1:25000 map sheets were used to produce a digital base map of the study area. Two of the map sheets (92G/2a, 92G/2d) were compiled and printed in 1957-59, and the remaining two (92G/2g, 92G/2h) are updated editions current to 1968. All latitude/longitude coordinates from the map sheets were converted to Universal Trans Mercator grid coordinates using a program devised by Underhill Geographic Systems Ltd. Coordinates from 14 points located at road crossings throughout the watershed were used to register the map sheets that formed the base map. Registration error did not exceed 0.001 meters. Once registration was complete, various line work was digitized and placed on different GIS levels for processing (Table 4). Additional maps were incorporated into the digital base map in order to update the line work from the original map sheets. For example, 1:25000 Langley Municipal road maps were digitized to update the road network to 1979-80, and 1:5000 Municipal planning maps were digitized to further update the road network to 1989-90. Only map scales of 1:25000 or larger were registered to the base map throughout the study.

Table 4. Line work digitized from National Topographic map sheets to form digital base map.

Line Type	Number of Levels
Watershed Boundary	1
Contour Lines	1
Road Network	4
Stream Network	4
Railways	1
Gas Lines	1
Power Lines	1

4.1.2 1979-80 Land Use Mapping

In 1979, DeLeeuw and Stuart (1981) developed a 1:25000 "land use" map for MOE which was used in this study to produce a 1979-80 digital land use map. Land use maps from municipal and regional sources including Agriculture Land Reserve maps and Ministry of Agriculture land use maps, were used to generate the 1979 map (DeLeeuw and Stuart, 1981).

In addition to land use maps, it was later learned that district zoning bylaw maps were also used by DeLeeuw and Stuart to generate the 1979 map. In order to transform the 1979 map into an actual land use map, all polygons were verified and corrected by using 1979 1:10000 black and white air photographs (Maps B.C., Ministry of Crown Lands). Most of the adjustments made to the map (ie: polygon labels and boundaries) occurred in the lower and upper regions of the watershed. Once corrected, the map was registered to the base map and digitized using common boundary techniques with roads, streams and railway lines to improve digital accuracy.

A total of nine land use types are designated in the 1979 map legend which are defined by DeLeeuw and Stuart (1981) (Table 5). Two of the land uses, commercial and industrial, are combined for the 1979-80 digital land use map. Also, a category referred to as "land use not mapped within boundary" was added to the digital land use legend which represents differences in watershed boundaries between the base map and the various land use maps registered to the base map.

Table 5. Definitions of 1979 "land use" designations described by DeLeeuw and Stuart (1981).

Agricultural	- a use providing for the growing, producing and harvesting of agricultural products; includes mushroom growing and the keeping of animals and birds
Residential	- a use providing for the accommodation and home life of a person of persons
Undeveloped	- land for which the best use has not been designated (includes non-commercial forest and idle land)
Commercial	- a use providing for the selling of goods and services
Industrial	- includes areas where goods and services are processed, fabricated, assembled, stored, transported and distributed.
Extraction	- a use providing for the extraction, grading, crushing, screening and storage of sand, gravel, minerals and peat
Transportation/ Utilities	- major transportation corridors and support services
Institutional	- a use providing for government functions and services; includes schools, hospitals, prisons and community centres
Recreational	- a use providing for outdoor recreation and open space

4.1.3 1989-90 Land Use Mapping

Three 1989 land use maps produced by Sawicki and Runka (1990) at a scale of 1:10000 (prepared for and supplied by Langley Municipality) were used to develop a 1989-90 digital land use map for the study area. The three maps used (#1,#2, and #4) covered approximately 90% of the area within the watershed boundary as defined by the digital base map. Sawicki and Runka used extensive ground truthing with the aid of 1984 air photographs to produce the 1989 maps. Land use was classified as to land "activity" (approximately 178 different land use types) and land "cover" according to the classification described by Sawicki and Runka, 1986.

The number of land use types established by Sawicki and Runka in 1989 were generalized in two stages (Table 6). The first stage involved grouping 178 land use codes into 28 categories (referred to in this study as "detailed land use") for analysis in relation to fish habitat areas. The second stage involved taking the 28 categories and further generalizing down to 9 land use types (referred to in this study as "general land use") which correspond to the land use designations described by DeLeeuw and Stuart (1981). This was done to facilitate an assessment of temporal land use change over a 10 year period between the two digital maps.

Before incorporating the 1989 maps into digital form, some adjustments were made to update the data, specifically areas of residential development in the middle regions of the watershed. Municipal planning maps at a scale of 1:5000 were used to update the obvious polygons that had undergone change. Once the 1989 maps had been generalized, coded and updated, the three maps were registered to the base map and digitized using common boundary techniques with roads, streams, railway lines and polygon boundaries from the 1979-80 digital map. This technique reduced the number of sliver polygons created during subsequent overlay procedures.

Table 6. Land use classes generalized from codes developed by Sawicki and Runka (1986) and used to produce a detailed and general land use data base for the 1989-90 digital map.

General Land Use	Detailed Land Use	* Land Use Codes
Agricultural	Crop Production	A100-A190
	Livestock Production	A200-A233
	Other Agriculture	A240-A290
	Agri-Forestry	F100-F200
Residential	Residential	D100-D290
Undeveloped	Former Agriculture	B100
	Former Forestry	B200
	Former Extraction	B300
	Former Recreation	B400
	Former Residential	B500
	Former Transportation, Storage, Commercial, Institution	B600-B900
	Undeveloped/No Activity	N000
Commercial	Wholesale/Retail/Service/ Storage	C100-C300, M500-M590,M900
	Aquaculture Production	Q100-Q200
Industrial	Manufacturing	M100-M400
	Treating/Disposal of Wastes	M600-M690
Extraction	Surface Extraction	E100-E190
	Underground Extraction	E300
Transport/ Utility	Highways	H110
	Railways	H120
	Airports	H130
	Communication Activities	H200
Institutional	Institutional Services	J100-J900
	Flood Control and Drainage	P200
Recreational	Fish and Wildlife Activities	G100-G229
	Land Dependent Recreation	R100-R190
	Indoor/Outdoor Recreation	R200-R220
	Land for Research and Conservation	P100

* See Sawicki and Runka (1986) for definitions of land use codes.

4.1.4 Land Use Distribution Categories

To compare the distribution of land use within the study area, a number of categories were set up to represent overall land use conditions, land use occupying a 500 m buffer around the stream network, and land use occupying 500 m buffer segments around key fish habitat reaches (Figure 9 and Figure 10). The segments around the fish habitat reaches are not intended as specific buffer widths for management purposes. A total of nine different categories were examined: i) overall watershed conditions (OW); ii) overall buffer of the entire stream network (OB); iii) a buffer of all habitat study reaches in Coghlan Creek and Salmon River (CS); iv) a buffer of the Coghlan Creek study area (C); v) a buffer of the Salmon River study area (S); vi) a buffer of the first study reach in Coghlan Creek (C1); vii) a buffer of the second study reach in Coghlan Creek (C2); viii) a buffer of the first study reach in Salmon River (S1); and ix) a buffer of the second study reach in Salmon River (S2). The Coghlan Creek and Salmon River study areas are defined by reaches C1/C2 and S1/S2 respectively which correspond to fish habitat evaluation sites that are described later in section 4.2. The symbols OW, OB, CS, C, S, C1, C2, S1 and S2, are used throughout this paper to represent the spatial categories for both the 1979-80 and 1989-90 digital data bases. All 500 m buffers are defined as 250 m from either side of the stream.

4.1.5 1979-80/1989-90 Land Use Changes

In order to quantify temporal changes in land use for the

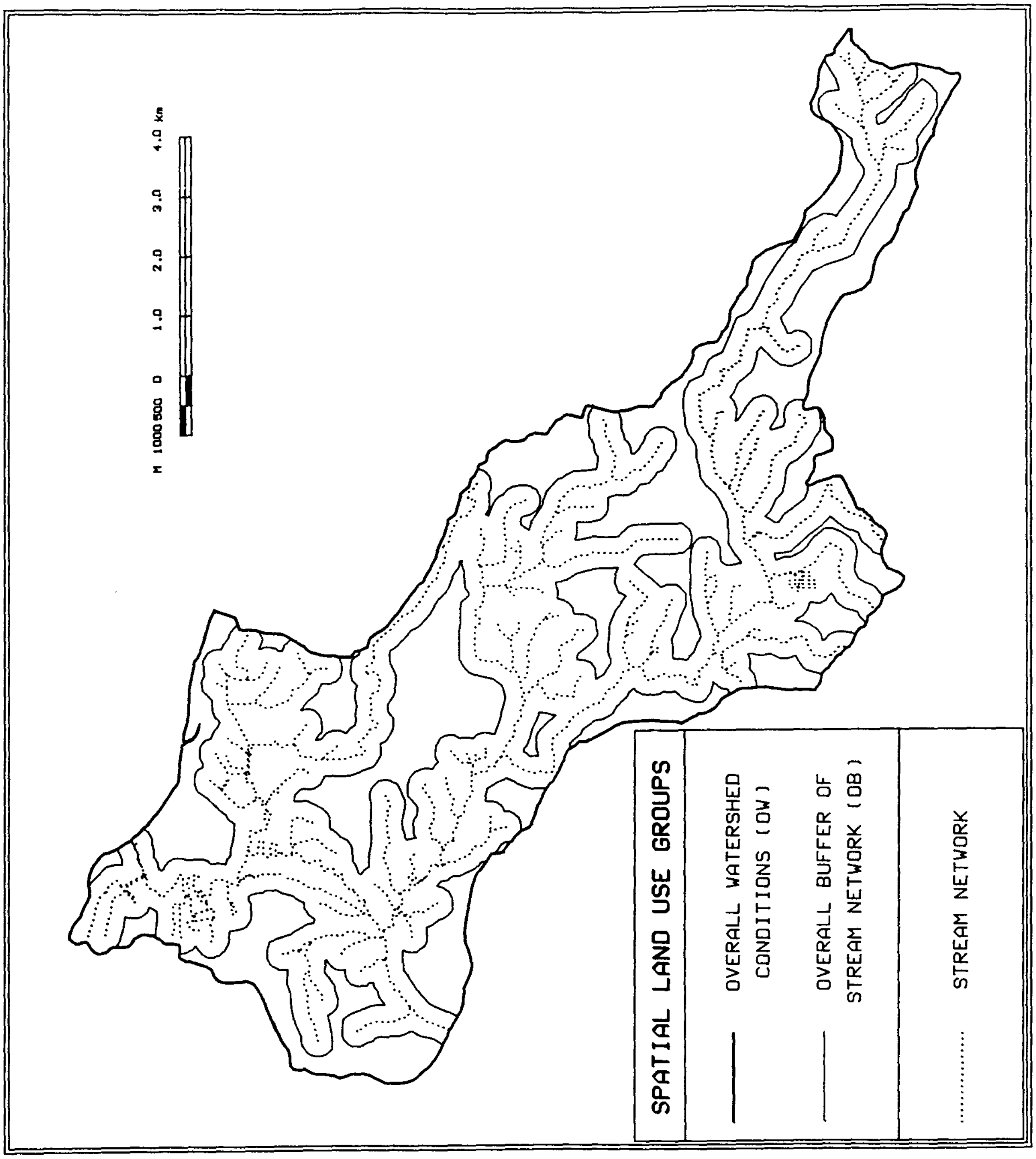


Figure 9. Comparative land use distribution categories OW (overall watershed conditions) and OB (overall buffer of the entire stream network). Note: Stream buffers are 500m wide - 250m from either side of stream.

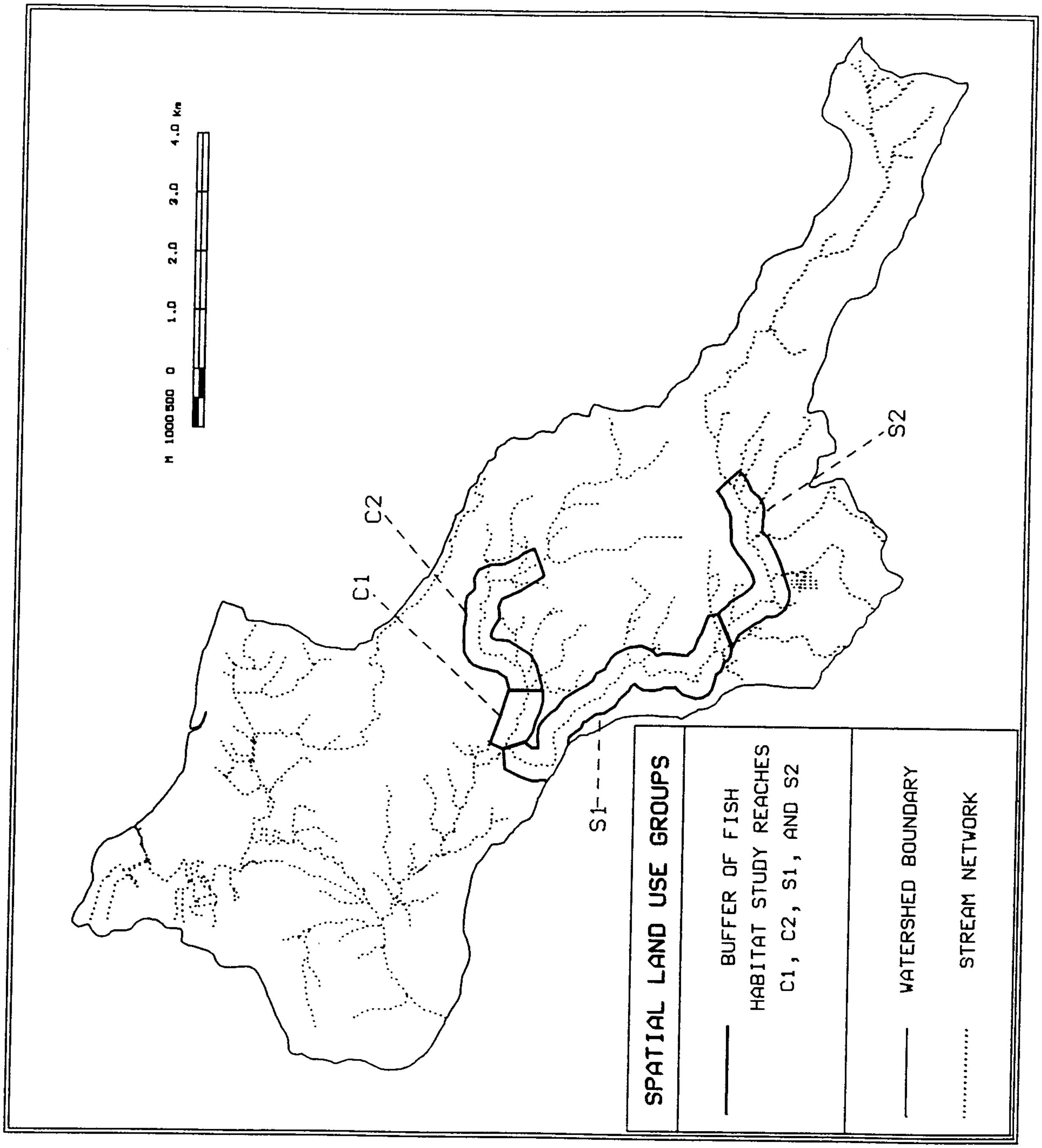


Figure 10. Comparative land use distribution categories C1, C2, S1 and S2, which represent buffers around critical fish habitat areas. The Coghlan Creek buffer is represented by C1 and C2, and the Salmon River buffer is represented by S1 and S2.
Note: Buffers are 500m wide - 250m from either side of stream.

study area, a series of GIS overlays was executed using the digital data bases produced for 1979-80 and 1989-90. All nine spatial categories defined in section 4.1.4 were employed in the overlay functions. This analysis provided information on the dynamics of recent changes among various land use types.

Although there are nine general land use types described in sections 4.1.2 and 4.1.3, only agricultural, residential and undeveloped areas are emphasized in identifying temporal land use trends because of the large proportion of the watershed they represent. The other six land use types have limitations associated with generating temporal trends because they occupy small geographic areas at a 1:25000 scale. This is particularly relevant for industrial, commercial and extractive land uses.

Before the various GIS overlays were conducted, each digital data base was converted from a vector data structure to a raster format. The raster data structure was defined using a 15x15 m grid cell which was determined to be an appropriate resolution in relation to the scale of the project. Once a particular overlay was processed, a new data base was created which could then be queried for land use change.

4.1.6 Cumulative Analysis of 1989-90 Land Use

A cumulative evaluation of land use patterns using the 1989-90 detailed data base was conducted for the buffer segments of Coghlan Creek (C) and Salmon River (S). This analysis provided information on how sensitive important fish habitat reaches are to streamside land use in the basin.

To obtain a downstream cumulative land use pattern, each upstream habitat buffer (C2 and S2) was compared to both habitat buffers for each study reach combined (C and S). Because each habitat buffer segment was different in size, all areas were computed to percent values. The Coghlan Creek and Salmon River study reaches are compared to assess which stream is more prone to land use pressures.

4.2 Evaluation of Fish Habitat

Most researchers who have studied salmonid fishes in the Salmon River watershed have recognized the middle reaches of the watershed as being the most productive (Hartman, 1965; Hartman, 1968; DeLeeuw, 1982; Schubert and Kalnin, 1990). In addition, fish habitat inventories conducted by McMynn and Vernon (1954), Erickson and Harding (1972), and DeLeeuw (1982), note that the capacity of habitat to produce fish is highest in the middle reaches. Given this information and after conducting a brief field survey of the stream network in May of 1990, it was determined that this middle region would be a good study area to investigate fish habitat characteristics in more detail.

Specifically, four stream reaches were chosen in the middle region of the watershed that feature important salmonid spawning and nursery rearing habitat. Two of the stream reaches (C1 and C2) are located on the mainstem of Coghlan Creek and the other two (S1 and S2) are located on the mainstem of the Salmon River (Figure 11). Similar to the spatial categories described in section 4.1.4, the Coghlan Creek (C) and Salmon River (S) study areas are defined by reaches C1/C2 and S1/S2 respectively. The symbol CS refers to all fish habitat study reaches in both Coghlan Creek and Salmon River.

Fish habitat data were collected in reaches C1, C2, S1 and S2 for 1980 and 1990 and are used in this study to characterize changes in physical fish habitat parameters over a 10 year period. The next two sections describe the 1980 and 1990 habitat inventories and sampling designs followed by two sections describing the method of comparison between the two sets of data.

4.2.1 1980 Habitat Inventory and Sampling Design

A 1980 fish habitat data base was developed for this study by extracting information from a Ministry of Environment VAX computer which contains habitat "unit" data collected during the early 1980's according to methods described in DeLeeuw, 1981. The 1980 habitat inventory itself was carried out by both Regional Provincial fisheries staff and the Fish Habitat Improvement Section as part of the Salmonid Enhancement Program (SEP). Part of the impetus for this work was to assess impacts of a 1979 winter flood event on the morphology, substrate composition, fish cover, and fish populations of the Salmon River. The results of the inventory are summarized in DeLeeuw, 1982.

Description of field techniques and sampling design for the 1980 habitat inventory are presented in DeLeeuw (1981, 1982). Field data collection was carried out on a site-specific basis within previously designated stream reaches. The reaches were partitioned according to stream gradient analysis from 1:25000 topographic maps and verified in the field using a Suunto optical clinometer (Model PM-5/360 PC). Within each reach, four different hydraulic units consisting of riffles, glides, pools and sloughs were recognized and used as sites for measuring a number a instream parameters at low flows during July and August (see Table 7 for definitions of hydraulic units). A minimum of six hydraulic units in a row were sampled at one location in a particular reach and another series of six units were sampled at another location within the same reach. Lesser numbers of hydraulic units were sampled where habitats were fairly uniform. Unfortunately, site selection was non-random and related mainly to accessibility, primarily at road/stream crossings (Sebastian, 1991).

Table 7. Description of hydraulic units recognized in the 1980 habitat inventory of Salmon River and Coghlan Creek (DeLeeuw, 1981).

Hydraulic Unit	Description
Riffle	- A shallow, high velocity area of a stream where the water surface is broken into waves by bed material wholly or partially submerged.
Glide	- A section of flowing water that is moderately deep with the surface unbroken by bed material.
Pool	- An area of the stream that is deep and has no velocity relative to contiguous hydraulic types.
Slough	- A very low velocity stream section having a uniform width and depth.

A total of six stream reaches (four in Coghlan Creek and two in the Salmon River) inventoried by MOE fisheries staff were used to develop the fish habitat data base for 1980. The four reaches in Coghlan Creek were combined into two reaches for this study due to the low number of sample sites evaluated in each of the original four reaches. The result was a data base with habitat information in four areas that correspond to reaches C1, C2, S1 and S2 as described in section 4.2. The type and number of hydraulic unit sample sites in each reach during the summer of 1980 are presented in Table 8.

Table 8. Type and number of hydraulic unit sites sampled by MOE in 1980 (DeLeeuw, 1982; Sebastian, 1991).

Stream Reach	Hydraulic Unit		# of Sites
C1	Riffle		11
	Glide		10
	Pool		3
	Slough		0
		Total	24
C2	Riffle		12
	Glide		4
	Pool		8
	Slough		0
		Total	24
S1	Riffle		6
	Glide		2
	Pool		4
	Slough		0
		Total	12
S2	Riffle		5
	Glide		4
	Pool		3
	Slough		0
		Total	12

DeLeeuw (1981) states that the number of units described (originally 12 units per reach) should adequately "characterize" each reach. No sloughs were selected in any of the reaches and the precise location of sample sites taken in each reach was not documented.

For each hydraulic unit, a number of physical instream variables were measured that emphasize available stream habitat and salmonid cover requirements. Following is a list of definitions (DeLeeuw, 1981) for parameters used to describe each hydraulic unit measured in 1980 and subsequently used to develop the historic fish habitat data base for this study.

1. Length (m): The length of the hydraulic unit being inventoried.

2. Wetted Width (m): The wetted width of the hydraulic unit at time of inventory. Where width is not uniform, the average width is recorded.

3. Area (m^2): Computed in the field by multiplying length by wetted width.

4. Depth (m): The average depth of the hydraulic unit being measured (employing full length and cross-section).

5. Volume (m^3): Computed by multiplying average depth, wetted width and length.

6. Channel Width (m): The mean width of the channel from rooted vegetation to rooted vegetation (terrestrial). Mean annual high water level is used in the absence of vegetation.

7. Velocity (m/sec): Recorded primarily to enable computation of discharge in a given reach. The measurement is usually taken in a riffle or glide where depth and wetted width are fairly uniform using the "float chip" method. At least 3 measurements are taken for each estimate to ensure "accurate" results.

8. Fines (%): Visual estimate of percent composition of streambed substrates in the size range 0.0-0.1 cm.

9. Small Gravel (%): Visual estimate of percent composition of streambed substrates in the size range 0.1-4.0 cm.

10. Large Gravel (%): Visual estimate of percent composition of streambed substrates in the size range 4.0-10.0 cm.

11. Cobble (%): Visual estimate of percent composition of streambed substrates in the size range 10.0-30.0 cm.

12. Boulder (%): Visual estimate of percent composition of streambed substrates greater than 30.0 cm. in diameter.

13. Instream Log (m^2): Pertains to the cover afforded to salmonids by debris piles, stumps, root wads, and fallen trees within the wetted area of the hydraulic unit under study.

14. Instream Boulders (m^2): A group of boulders (each boulder 30 cm. in diameter or larger) in reasonable proximity to each other which provide cover to salmonids. The measurement includes the actual area of the boulders because the interstices underneath also constitute cover.

15. Instream Vegetation (m^2): The area of submerged vegetation in the hydraulic unit being measured. It does not include algae covering the substrate.

16. Overstream Vegetation (m^2): A measure of overhead (organic) cover within 1 vertical meter of the water surface; the total area of the water surface with riparian vegetation leaning over it.

17. Cutbanks (m^2): A measurement of the eroded area within and beneath a stream bank which acts as holding areas for salmonids. Average depth (horizontally into the bank) multiplied by the length along the bank produces the area.

18. Temperature (°C): All thermometers are standardized prior to taking stream temperatures. The measurement is made by holding the entire thermometer underwater. Several readings are made to ensure accuracy.

A meter stick or metric tape was used to measure the length, wetted width, depth, channel width, instream log, instream boulders, instream vegetation, overstream vegetation and cutbanks.

4.2.2 1990 Habitat Inventory and Sampling Design

In order to formulate a 1990 fish habitat data base for this study, a comprehensive inventory was conducted to establish an information base. The first phase of this inventory was to obtain a complete record of all hydraulic units within the Coghlan Creek (C) and Salmon River (S) study areas. This phase is referred to as the "general survey". The second phase required taking selective samples of hydraulic units from the general inventory and measuring the same physical fish habitat parameters used to develop the 1980 fish habitat data base. This phase is referred to as the "detailed inventory". For the 1990 field season, all measurements and notations were recorded from August 1 to September 27. Although different volunteers helped at various times throughout the two months of field work, the author was present at every field site during data collection to ensure an accurate and consistent data set.

Prior to initiating the habitat inventory on August 1, a staff gauge was installed in both the Coghlan Creek and Salmon River study areas to give a relative indication of stream flow on a day to day basis during the sampling period. This was done because many of the physical characteristics of a hydraulic unit (e.g. wetted width) are greatly influenced by stream flow. Any sampling, therefore, should be done under similar flow conditions to obtain comparable results between hydraulic units.

Each staff gauge was secured in the substrate approximately 25 meters above the Coghlan Creek/Salmon River confluence. Before each sampling day, the staff gauge height and stream temperature were recorded (usually between 8:00 am and 9:00 am) at each station (Table 9). As Table 9 reveals, very little variation in gauge height occurred between sampling days in either Coghlan Creek or Salmon River.

Table 9. Staff gauge height readings and stream temperatures taken at Coghlan Creek and Salmon River study area stations during the 1990 habitat inventory.

Date	Coghlan Creek		Salmon River	
day/mo	Gauge (m)	Temp (°C)	Gauge (m)	Temp (°C)
01/08	0.260	14.0°	0.090	16.0°
13/08	0.255	15.0°	0.070	18.0°
14/08	0.250	14.0°	0.080	17.0°
15/08	0.250	14.0°	0.080	17.0°
16/08	0.255	14.5°	0.080	17.5°
17/08	0.260	14.5°	0.080	17.0°
18/08	0.260	14.0°	0.080	17.0°
19/08	0.260	14.0°	0.080	16.0°
20/08	0.260	14.5°	0.080	16.5°
21/08	0.260	14.0°	0.080	16.5°
22/08	0.260	13.5°	0.100	16.0°
30/08	0.260	13.0°	0.080	14.5°
02/09	0.260	14.0°	0.090	15.5°
11/09	0.260	14.0°	0.090	15.5°
12/09	0.260	13.0°	0.100	15.0°
13/09	0.260	12.0°	0.100	16.0°
15/09	0.260	12.5°	0.100	14.0°
17/09	0.270	13.0°	0.130	14.5°
18/09	0.260	12.0°	0.120	13.5°
19/09	0.260	13.0°	0.110	14.0°
20/09	0.260	12.0°	0.120	13.0°
22/09	0.260	12.5°	0.110	14.0°
23/09	0.260	12.5°	0.120	14.5°
25/09	0.260	12.0°	0.100	13.5°
27/09	0.260	12.5°	0.090	13.5°

The general inventory of all hydraulic units within the study areas of C and S was initiated at the Coghlan Creek/Salmon River confluence. Each hydraulic unit was identified according to DeLeeuw's (1981) classification and measured for length, wetted width, depth, and general substrate characteristics (i.e. %fines, %gravel, %boulder). Additional comments were also noted for each hydraulic unit such as rootwad formations, boulder clusters, overstream vegetation, tributary inputs, and various forms of barriers (barbed fences, culverts, beaver dams, etc.). Each hydraulic unit was then coded and grouped into reach breaks that were marked on 1:25000 black and white air photographs. The number of reach breaks that occupied any given study reach (C1, C2, S1 or S2) depended on the number of field reference points (e.g. telephone poles, houses, roads, stream meanders) that could be identified on the air photos. This system was designed to aid in the location of specific hydraulic units (during the same low flow period) once the general inventory was complete. Unlike the 1980 inventory, all four hydraulic unit types (including sloughs) were identified and sampled in the study area.

The general survey formed the basis for selection of hydraulic units that were measured in more detail for characteristics of fish habitat. This was done by using random number tables for selection of sites. The number of sites chosen are representive of at least five percent of each hydraulic unit type. A total of 12 riffles, 12 glides, six pools, and six sloughs were selected from reach C and reach S for a sum of 72 sample sites. The type and number of hydraulic units sampled within the designated reaches of C1, C2, S1 and S2 are presented in Table 10. The general location of these sample sites is shown in Figure 11.

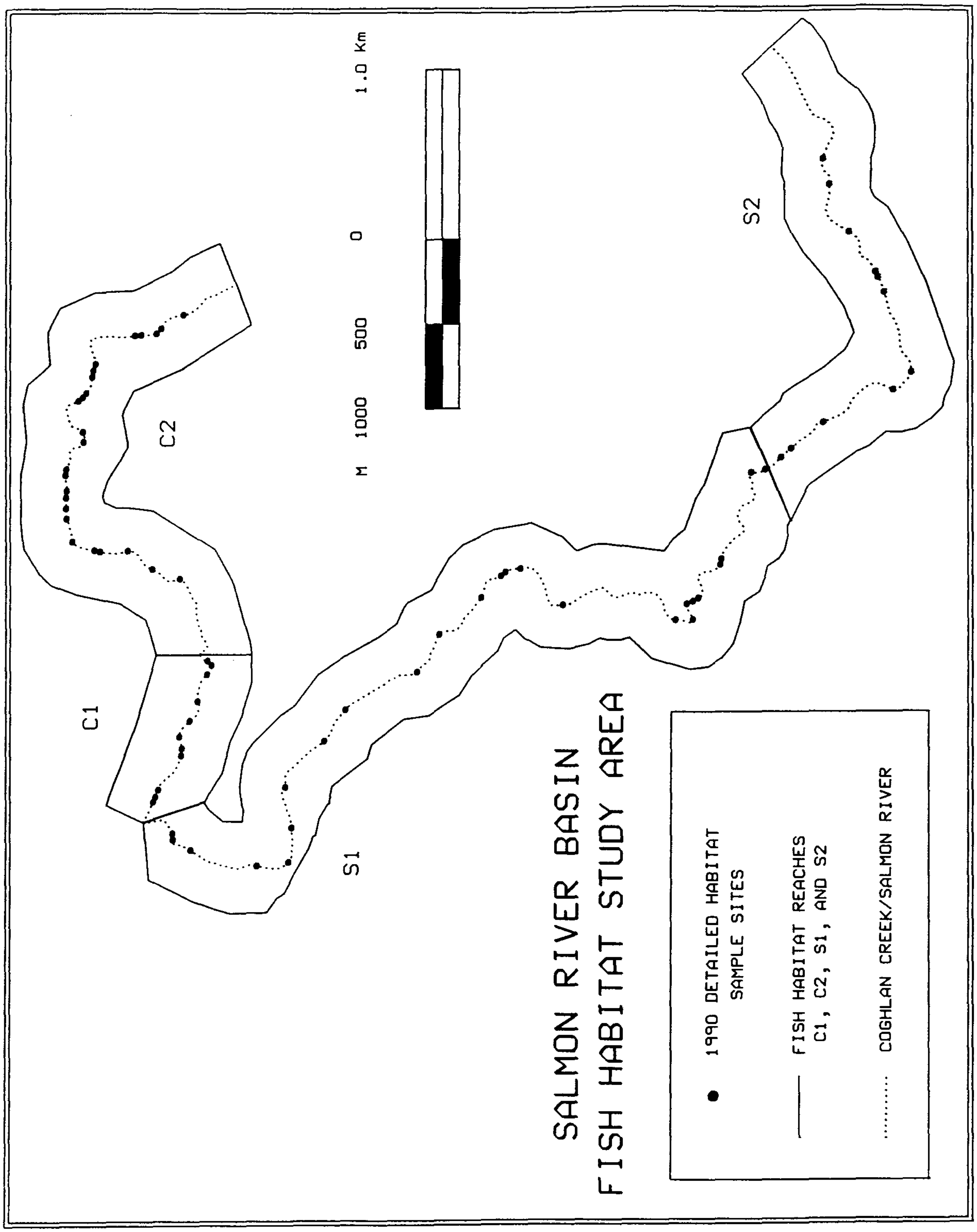


Figure 11. Fish habitat study areas in Coghlan Creek (reach C1 and C2) and the Salmon River (reach S1 and S2). Also, location of the 1990 detailed habitat inventory sites.

By examining the 1:25000 air photographs, it was possible to find each selected hydraulic unit that was to be sampled for the detailed inventory. Additional information from physical stream descriptions made during the general habitat survey helped in identifying hydraulic units. The same variables measured in the general survey (i.e. length, wetted width, and depth) were measured again to verify the site. After each site had been located, flagging tape marked with its original code was fixed (usually around a tree) above the high water mark.

Table 10. Type and number of hydraulic unit sites sampled in the 1990 detailed inventory corresponding to reach C1, C2, S1 and S2.

Stream Reach	Hydraulic Unit		# of Sites
C1	Riffle		4
	Glide		4
	Pool		2
	Slough		1
		Total	11
C2	Riffle		8
	Glide		8
	Pool		4
	Slough		5
		Total	25
S1	Riffle		9
	Glide		9
	Pool		4
	Slough		3
		Total	25
S2	Riffle		3
	Glide		3
	Pool		2
	Slough		3
		Total	11

The same physical fish habitat parameters defined by DeLeeuw (1981) and used to develop the 1980 fish habitat data base were measured for each of the selected hydraulic units in 1990. In some cases, a more thorough methodology was followed or a new technique was employed to obtain data for a given parameter. As well, some additional parameters were measured to supplement the data base. The following list outlines any changes in data collection techniques and additional parameters measured in 1990 that differ from the 1980 habitat inventory as described in section 4.2.1.

a) Wetted Width: Where width is not uniform, the average is determined by: a) averaging the width of 2 transects if the hydraulic unit is 0-5 m in length; b) averaging the width of 3 transects if the hydraulic unit is 5-20 m in length; c) averaging the width of 4 transects if the hydraulic unit is 20-50 m in length; and d) averaging the width of 5 transects if the hydraulic unit is over 50 m in length.

b) Depth: Taken at 3 points (1/3, 1/2, 2/3) along each wetted width transect and averaged.

c) Channel Width: Where width is not uniform, the average is determined from the same transects described for wetted width for each hydraulic unit. Each transect is measured from rooted vegetation to rooted vegetation or at the mean annual high water level.

d) Velocity: Recorded primarily to enable computation of discharge (m^3/s^{-1}) in a given reach. The measurement is taken in riffles or glides where depth and wetted width are fairly uniform. Mean water column velocity is measured with an Ott flow meter at 0.6 depth from the surface using the appropriate propellers. Velocity measurements are taken at 3 points (1/3, 1/2, 2/3) along at least one wetted width transect and averaged for each hydraulic unit.

Additional Parameters

1. Thalweg (m): A measurement of the deepest point in each hydraulic unit. The distance from the thalweg to the closest stream bank is also noted.

2. Surface Substrate (cm): A substrate particle is randomly selected along each wetted width transect. If the wetted width of a hydraulic unit is less than 1 m, a substrate sample is taken at every 0.25 m along the transect. If the wetted width of a hydraulic unit is greater than 1 m, a substrate sample is taken every 0.5 m along the transect.

4.2.3 1980/1990 Fish Habitat Comparison

In order to compare physical fish habitat changes over a 10 year period in the Coghlan Creek and Salmon River study area, a number of changes to the 1980 and 1990 detailed inventory data bases were made. First, because no sloughs were inventoried in 1980, the sloughs measured in 1990 were discarded from the data base. Secondly, only parameters measured in both years that had similar data collection techniques were used in the analysis. Lastly, only stream reaches as a whole can be compared between the two years because hydraulic unit site locations within each reach were not documented in 1980.

4.2.4 Statistical Analysis

A statistical comparison was made between the four types of hydraulic units identified in the 1990 general survey. A t-test was carried out to determine the extent of differences in the morphological and general substrate conditions between the sample types. The t-test was appropriate because the sample numbers were relatively large and most variables were normally distributed. An analysis of variance was not carried out because of the uneven distribution of hydraulic unit sample numbers. Firstly, the overall differences between hydraulic units were tested (CS), and secondly, differences between Coghlan Creek (C) and the Salmon River (S) were compared.

The Mann-Whitney U test was used to determine if the hydraulic units measured in the 1990 detailed inventory were representative of those in the general survey. Only the parameters which are consistent in both data sets were used in the test. This non-parametric analogue was deemed appropriate for these analyses since not all variables met the requirements of normal distribution and equal variance.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Land Use Dynamics (1979-80/1989-90)

The Salmon River watershed occupies a total area of approximately 8070 ha (digital base map summary statistics). About 833 ha of the total watershed area is not covered with digital land use information due to differences in watershed boundaries between the various land use maps employed in the project. These "empty" polygons are evident in two land use distribution categories, namely the overall watershed (OW) and the overall stream network buffer (OB). All figures and tables that show land use patterns for 1979-80 and 1989-90 are generated using 8 standardized land use types for both digital maps. Only agricultural, residential and undeveloped areas are emphasized in temporal analyses. All other land use type changes were smaller than the accuracy of the digital data and therefore no significant trends could be discerned.

In the next four sections, the distribution of land use between the overall watershed, the overall stream network buffer, and the four buffered fish habitat reaches are compared, spatially and temporally. Section 5.1.5 outlines the variation of temporal land use change among all nine designated land use distribution categories. The last section (5.1.6) describes the cumulative distribution of land use within the four buffered fish habitat reaches using the 1989-90 detailed digital data base.

5.1.1 Overall Watershed Land Use Patterns and Temporal Changes

The 1979-80 digital land use map, as shown in Figure 12, illustrates that agricultural, residential and undeveloped areas occupied the majority of the watershed. Of the three land use types, it is evident that agriculture was the dominant land use occupying 59% of the total area. Residential regions, occupying 4% of the area, were concentrated in the northern regions of the basin, primarily in the town of Fort Langley. About 21% of the basin was undeveloped (including non-commercial forest land), of which a large proportion was no doubt vulnerable to various development initiatives. Many of the undeveloped regions depicted in Figure 12, however, are situated in steeply sloped riparian areas along the middle reaches of the basin which are difficult to develop.

The 1989-90 digital land use map, as shown in Figure 13, is slightly more complex. It shows that agricultural, residential and undeveloped lands still occupy a majority of the basin after a 10 year period. Given that 50% of the total area remained under agriculture, it could still be considered a rural area. Residential areas, occupying 7% of the total area, expanded into the middle regions of the basin closer to sensitive fish habitat areas. The amount of undeveloped land increased over the 10 year period, even though the parcels, accounting for 25% of the total area, seem to be more subdivided than in 1979-80.

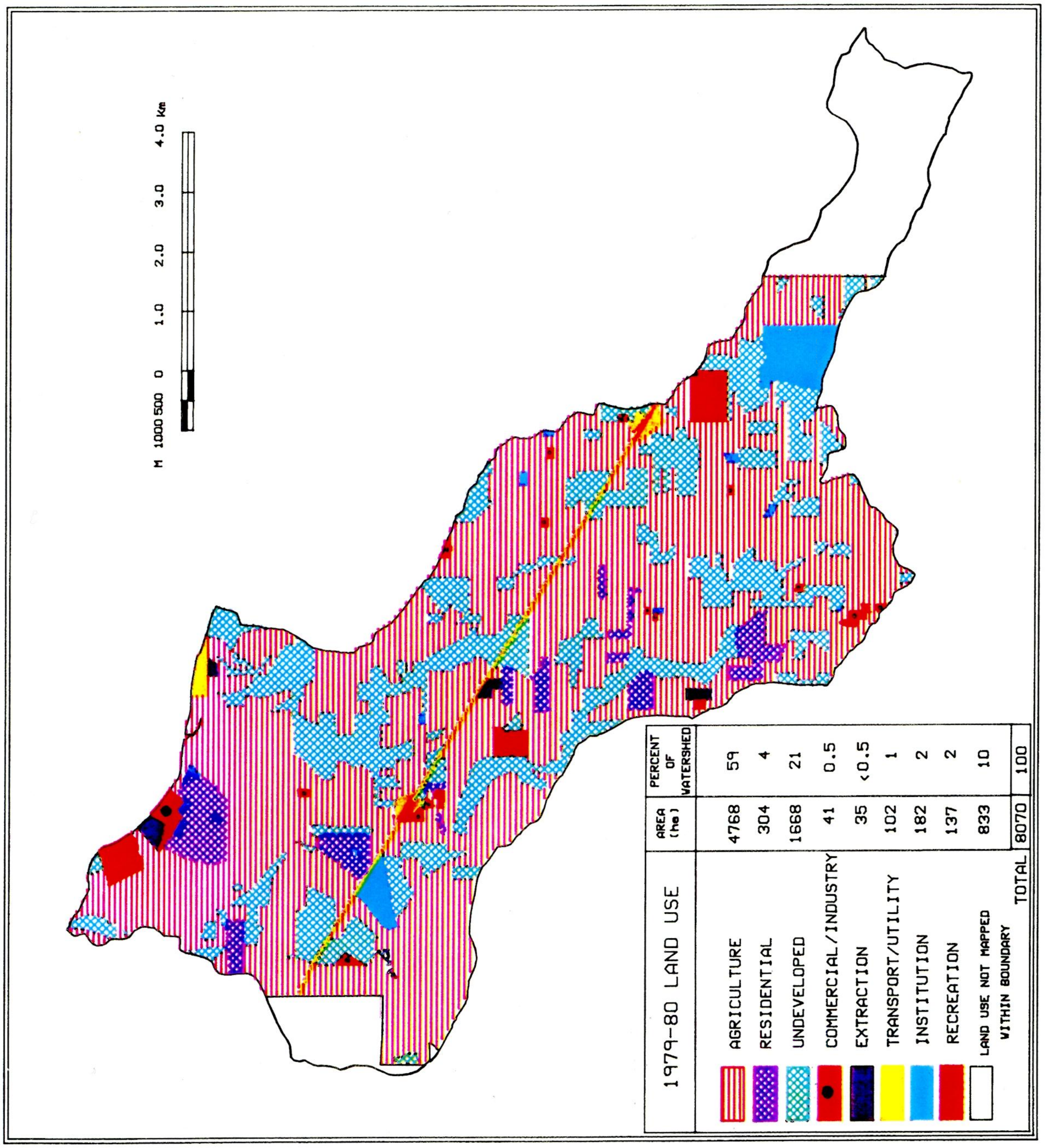


Figure 12. The 1979-80 land use map of the Salmon River watershed (OW).

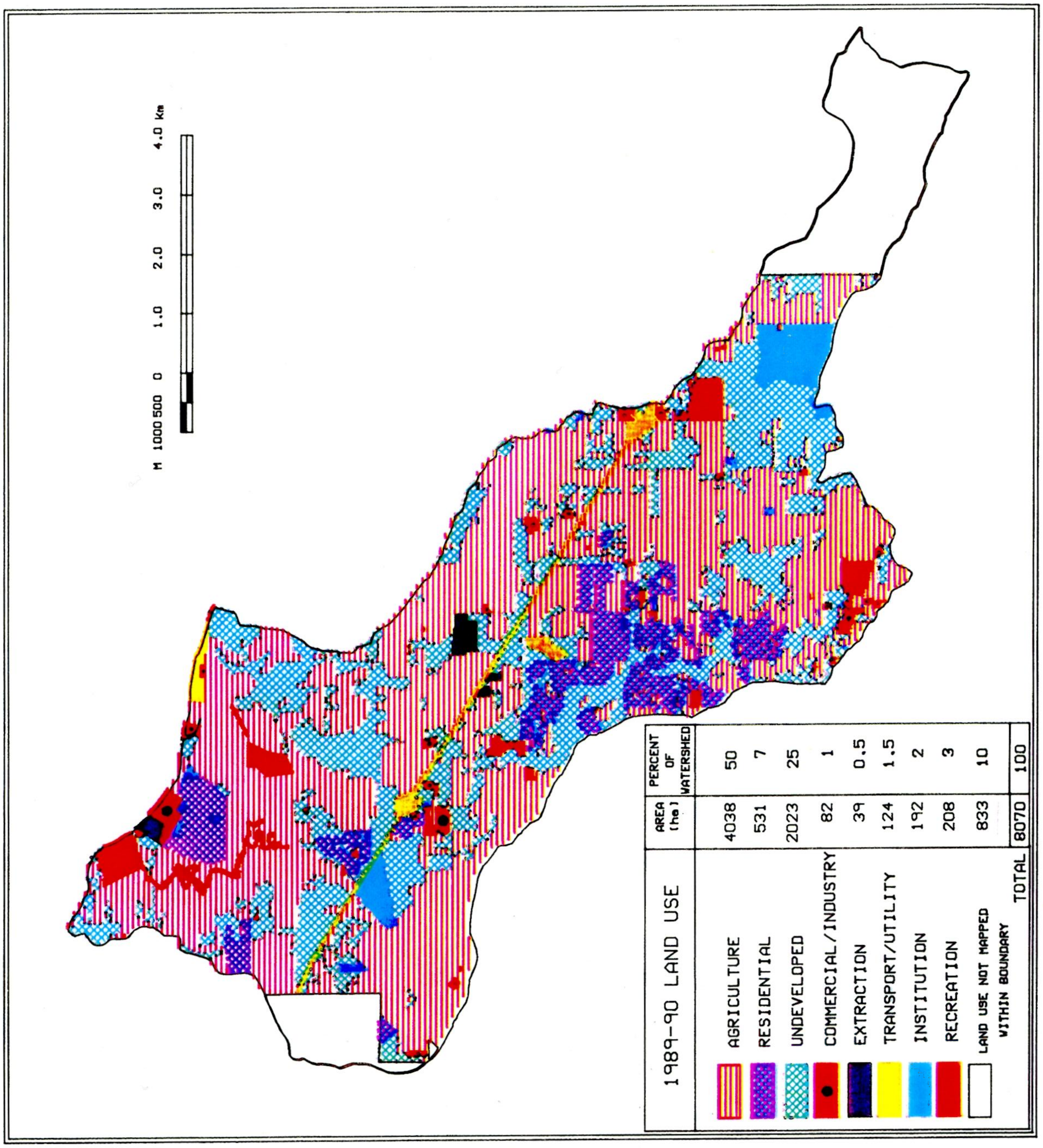


Figure 13. The 1989-90 land use map of the Salmon River watershed (OW).

Figure 14 illustrates the dynamics of temporal land use change among agricultural, residential and undeveloped areas for the distribution category OW. The greatest amount of change occurred in agriculture with a 9% overall decrease. Most of the agricultural land (951 ha) was taken out of production and designated as undeveloped suggesting that at least some portion of the land was withdrawn from the Agricultural Land Reserve (ALR) and held in speculation for urban development. About 254 ha of agricultural land went directly into residential development contributing to an overall increase of 3%. Only 38 ha of undeveloped land went directly into residential development. Although the overall increases in residential development were relatively small, the trend towards urbanization is clearly visible with the overall decrease in agriculture and increase in undeveloped areas (4%), most of which are likely targeted for future residential development.

5.1.2 Overall Stream Buffer Land Use Patterns and Temporal Changes

The most surprising statistic concerning the 500 m buffer generated around the entire stream network is that it occupies about 66% of the entire watershed area. In other words, a large proportion of the land based activities within the watershed are close to streams - many of which can have serious implications to the water resources and riparian regions of the basin. The following describes some of the major land uses within the buffer zone and examines temporal change.

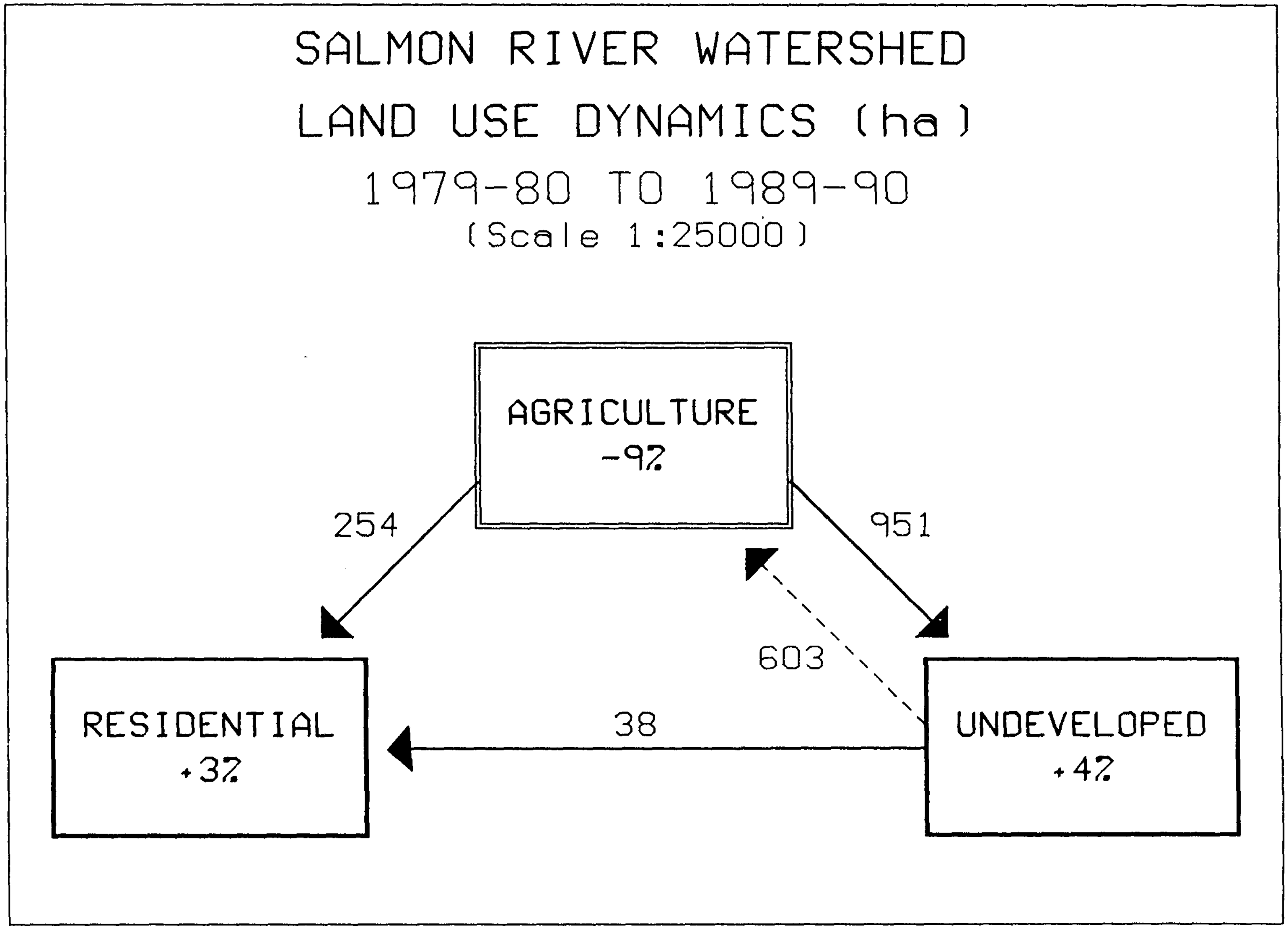


Figure 14. Overall watershed (OW) land use changes (ha) among agricultural, residential and undeveloped areas - 1979-80 to 1989-90.

The 500 m stream network buffer zone produced for 1979-80, shown in Figure 15, contains 59% agricultural land, 3% residential land, and 24% undeveloped land. For 1989-90, agricultural land use covers 49%, residential land covers 5%, and undeveloped land makes up 30% of the area within the same buffer zone (Figure 16).

The dynamics of temporal land use change among agricultural, residential and undeveloped lands for the stream network buffer is depicted in Figure 17. The greatest amount of change occurred in agriculture with a 10% overall decrease. A significant proportion of the agricultural land (700 ha) was taken out of production and designated as undeveloped. This transition in land use contributed substantially to a 6% overall increase in undeveloped areas close to streams. Another 154 ha of agriculture went directly into residential development contributing to an overall increase of 2%. About 26 ha of undeveloped land went directly into residential development.

5.1.3 Comparison of Land Use Trends: Stream Network Buffer vs Overall Watershed Conditions

Table 11 shows the distribution of land use and temporal trends for the overall watershed conditions and the 500 m stream network buffer. By comparing the proportional changes over the 10 year period in both cases, it is evident that the decrease in agriculture is significant, and of the same magnitude for both the overall watershed and the stream buffer zone. Residential land use increases slightly in both cases. The proportion of

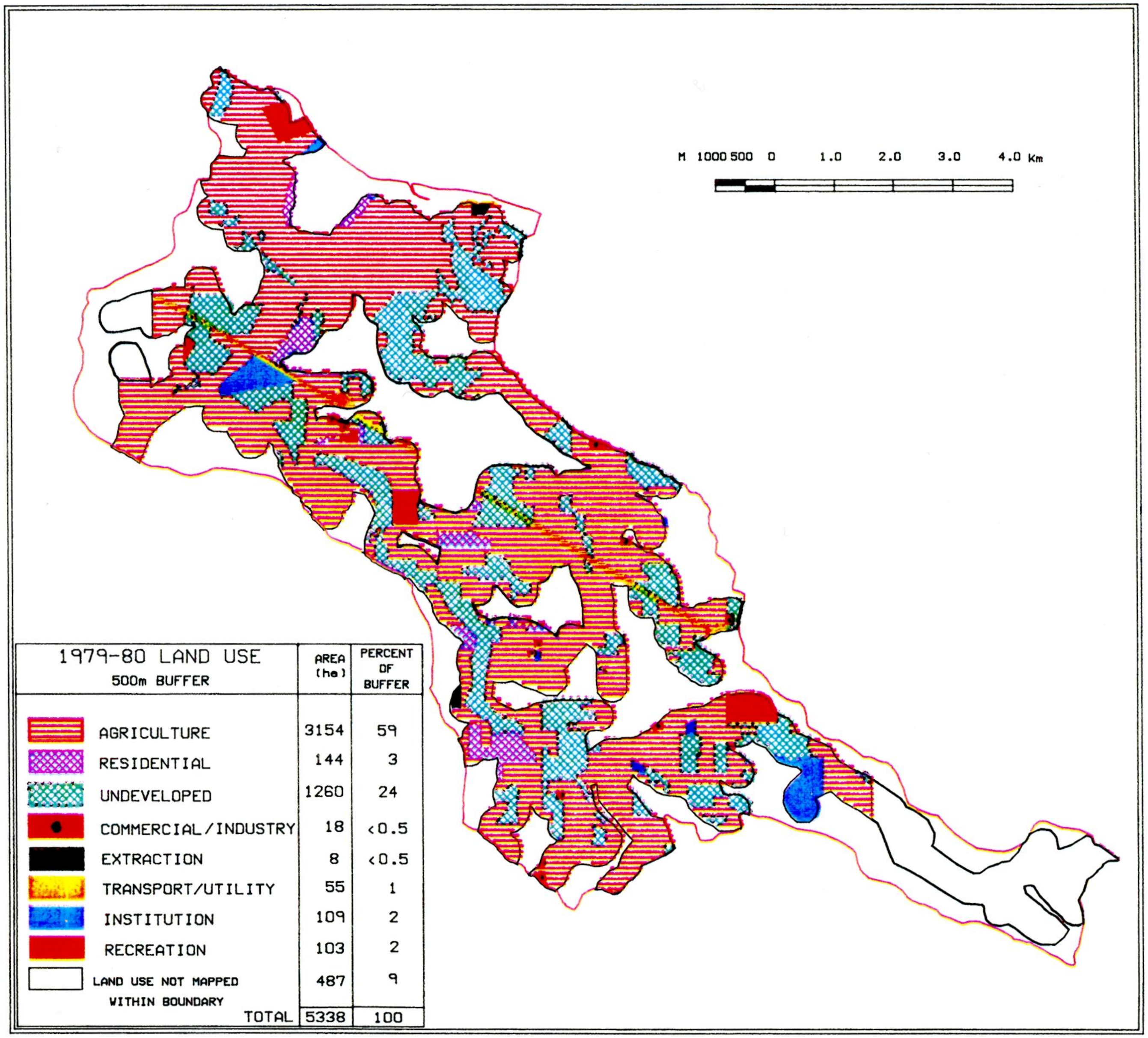


Figure 15. The 1979-80 land use map of the overall stream network buffer (OB).

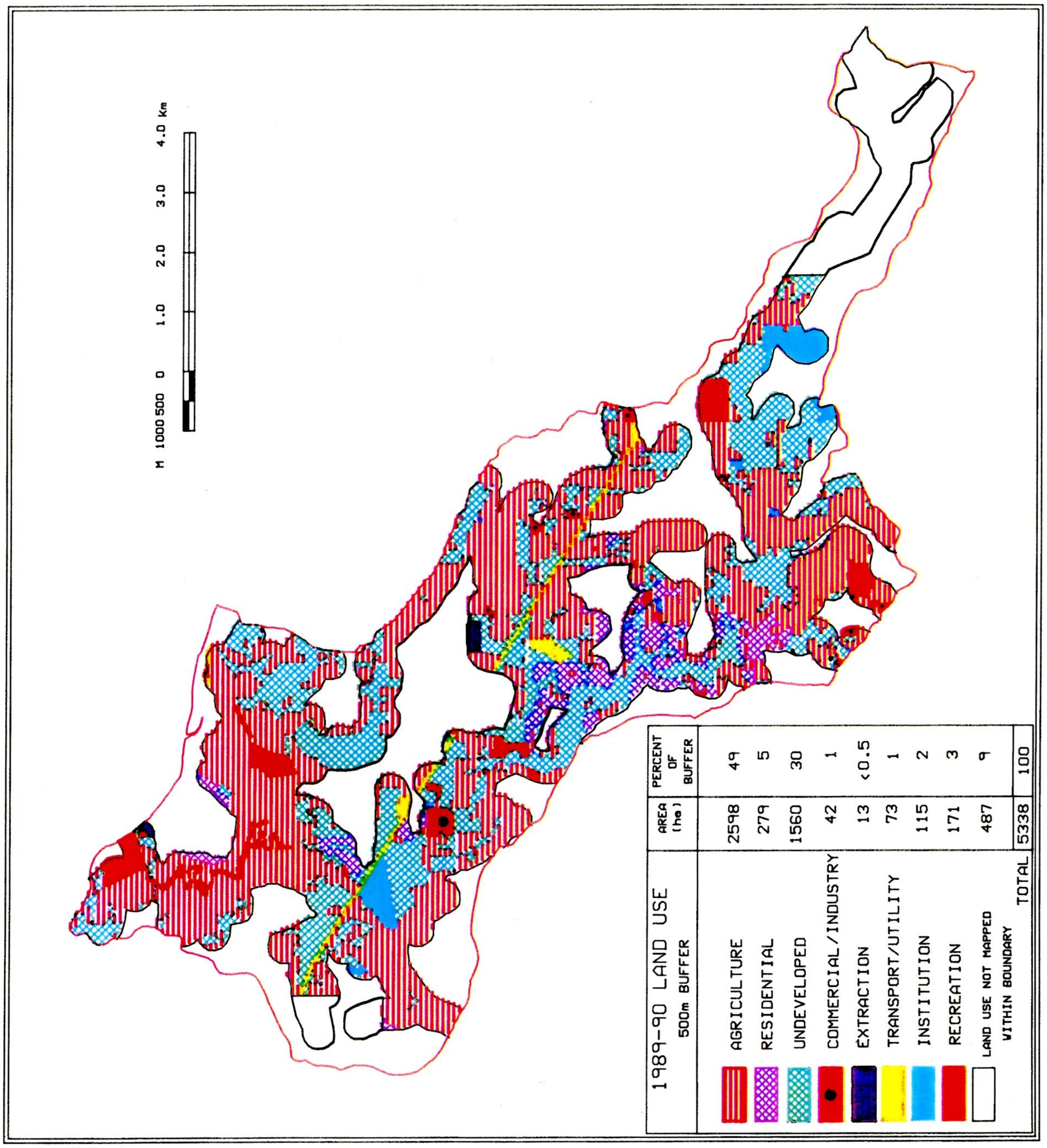


Figure 16. The 1989-90 land use map of the overall stream network buffer (OB).

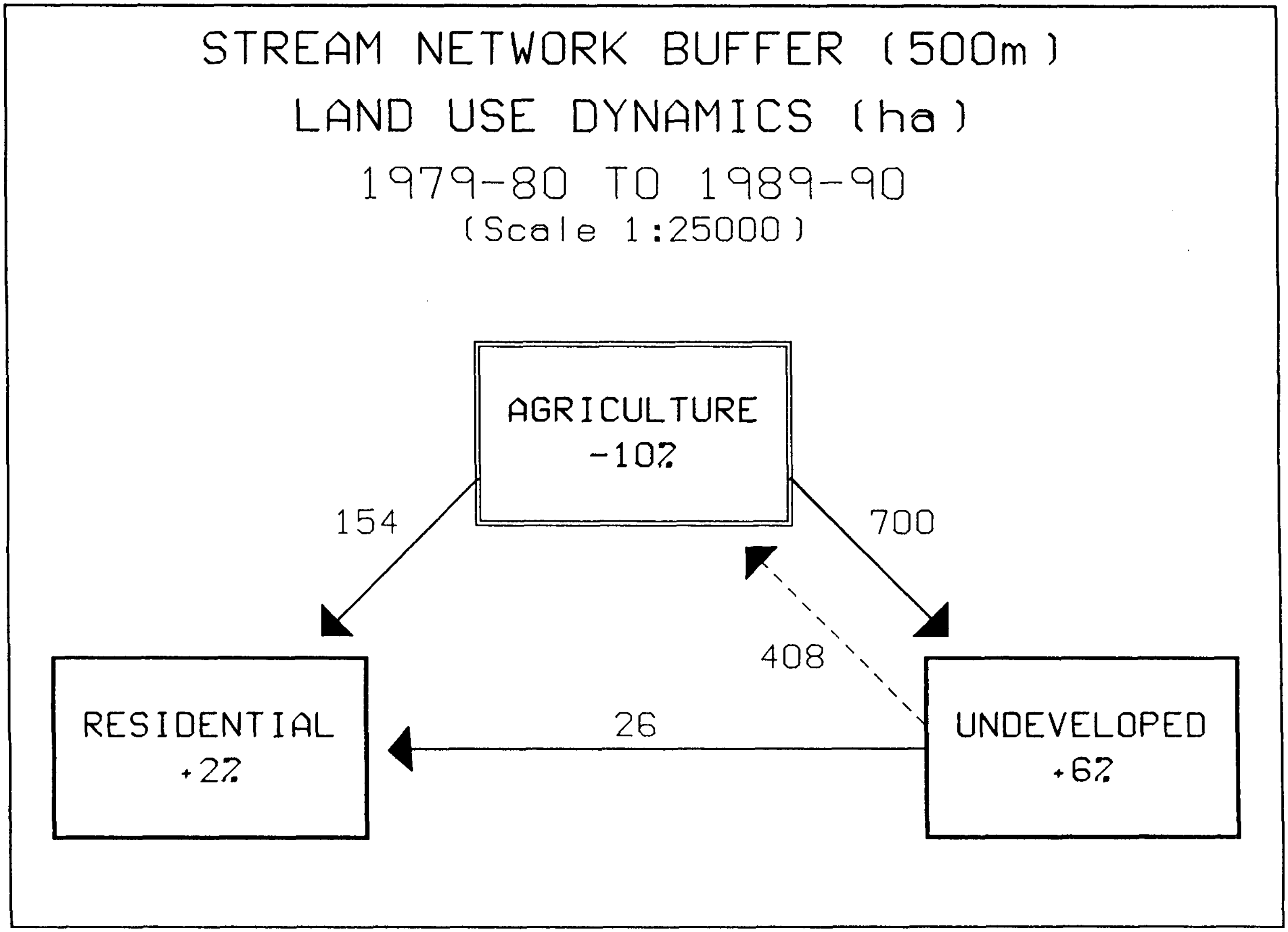


Figure 17. Changes in land use (ha) for the overall stream network buffer (OB) - 1979-80 to 1989-90.

undeveloped land increases in both areas but the increases are higher within the stream buffer zone. This is of some concern because much of this undeveloped land is vulnerable to residential development. Since the increases are higher within the more critical stream buffer zone, the potential for urban growth seems greater in areas that occupy space close to streams. This scenario has important ramifications to management of the aquatic environment, particularly the fisheries resource.

Table 11. Comparison of land use trends between the overall watershed conditions (OW) and a 500 m buffer of the stream network (OB). (1979-80 and 1989-90)

Land Use Class	Overall Watershed 1979-80	Overall Watershed 1989-90	Stream Network Buffer 1979-80	Stream Network Buffer 1989-90
Agriculture	59%	50%	59%	49%
Residential	4%	7%	3%	5%
Undeveloped	21%	25%	24%	30%

By comparing the overall watershed conditions to the stream buffer zone for each time period, it is evident that the differences in undeveloped areas are quite large. For 1979-80, the difference is 3% (21% vs 24%), and for 1989-90, the difference is 5% (25% vs 30%). This trend seems to indicate that there may be increasing urban development pressures in the future as more undeveloped sites become available close to streams. Again, this development scenario in turn could lead to detrimental impacts on the water quality and fisheries resource.

5.1.4 Land Use Patterns and Temporal Changes Associated with Key Fish Habitat Reaches

A more sensitive evaluation of land use patterns and temporal changes associated with critical fish habitat areas occur in buffer segments C1, C2, S1 and S2. Figures 18 and 19 illustrate the general land use patterns for 1979-80 and 1989-90 respectively. All four segments are combined for each time period.

Table 12 shows the percent change in land use in agricultural, residential and undeveloped land for all four segments. If the land use change is less than 3% for each segment, it is assumed to be insignificant and is not indicated in the table. Segments C1, C2, S1 and S2 have total areas of 56 ha, 178 ha, 274 ha and 165 ha, respectively.

Table 12. Percent land use change for buffered habitat reaches C1, C2, S1 and S2 (1979-80 to 1989-90).

	C1			C2		
Land Use	79/80	89/90	Diff.	79/80	89/90	Diff.
Agriculture	52	20	-32	57	53	-4
Residential	13	28	+15	5	5	--
Undeveloped	10	44	+34	35	35	--

	S1			S2		
Land Use	79/80	89/90	Diff.	79/80	89/90	Diff.
Agriculture	42	20	-22	69	63	-6
Residential	5	22	+17	5	5	--
Undeveloped	50	56	+6	23	32	+9

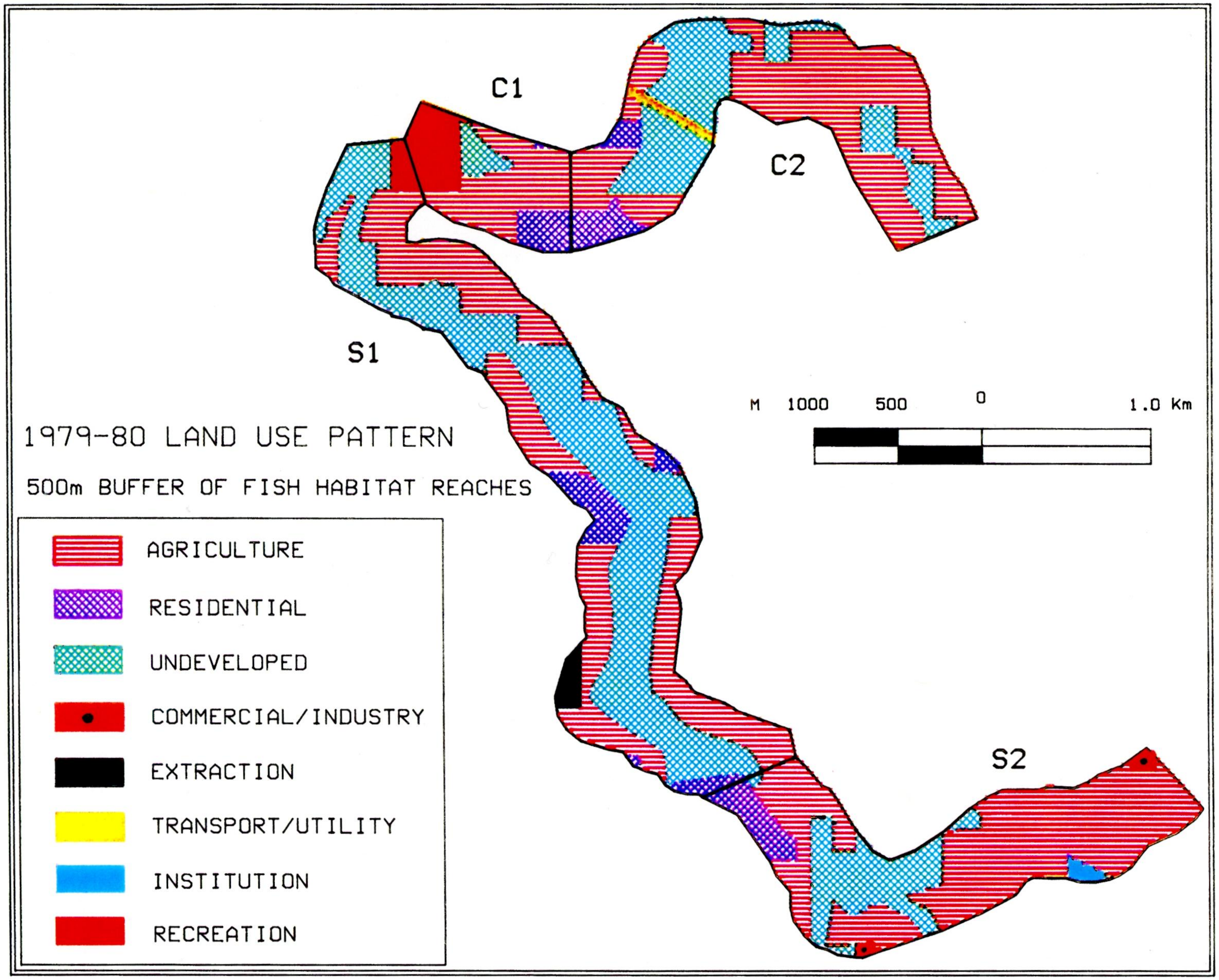


Figure 18. The 1979-80 land use map of buffered fish habitat reaches in Coghlan Creek (C1 and C2) and the Salmon River (S1 and S2).

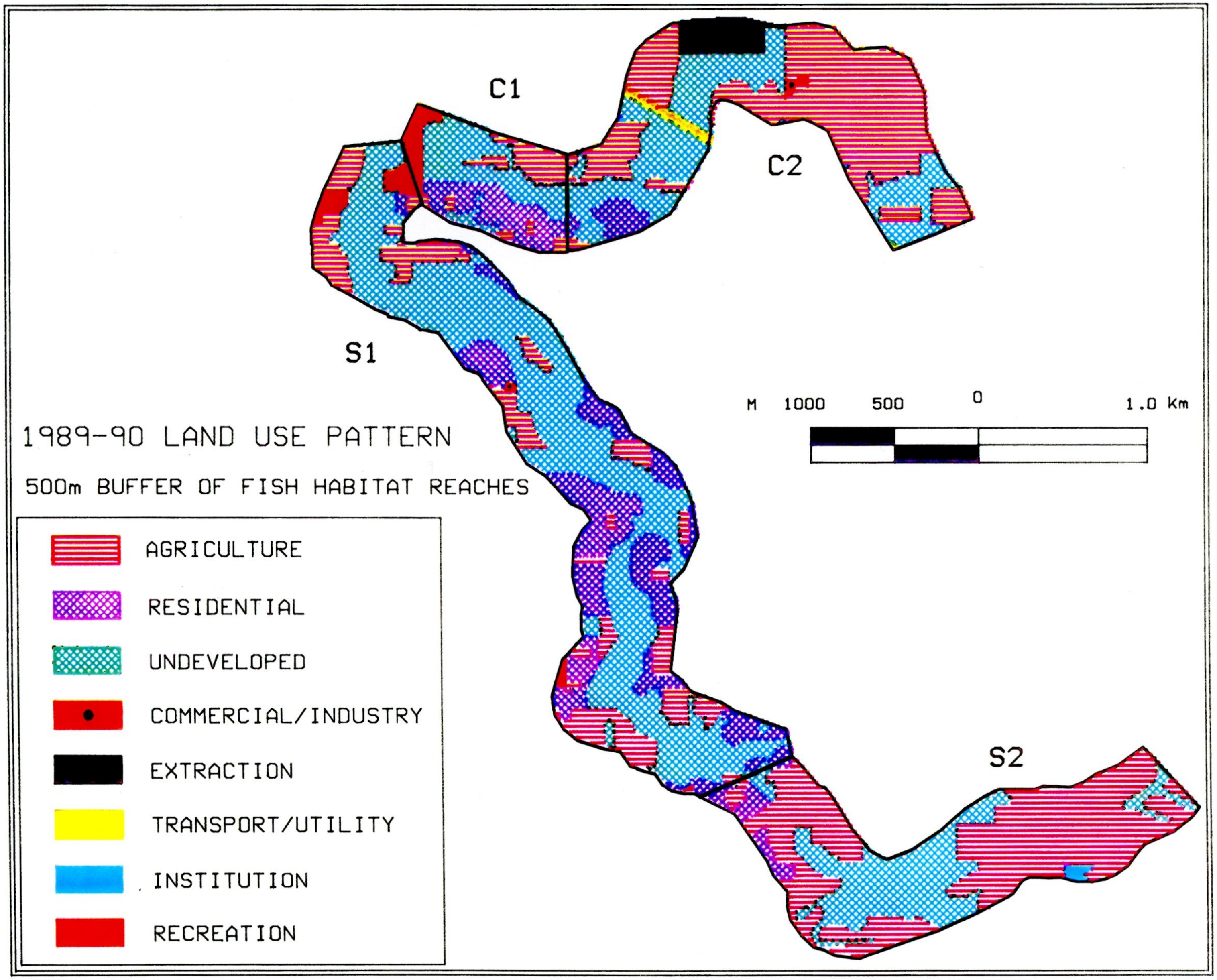


Figure 19. The 1989-90 land use map of buffered fish habitat reaches in Coghlan Creek (C1 and C2) and the Salmon River (S1 and S2).

For both time periods, segment S2 had the largest proportion of land in agriculture, segment C1 had the largest proportion in residential land, and segment S1 had the largest proportion of undeveloped land. Both C2 and S2 had the lowest proportion of residential land for both time periods. Overall, the smallest land use change occurred in segment C2 with a 4% decrease in agriculture and no significant change in residential or undeveloped areas. The largest land use change occurred in segment C1 with a 32% decrease in agriculture, a 15% increase in residential land, and a 34% increase in undeveloped areas. This trend strongly suggests that relative to the other three segments, the actual and potential urban development in segment C1 is extremely high.

A slightly more dynamic picture which shows the actual amount of land (ha) that went from one type to another over the 10 year period is presented in Figure 20. The largest portion of agricultural land taken out of production and designated as undeveloped was 46 ha, which occurred in buffer S1. Also in S1, a total of 30 ha of agriculture and 18 ha of undeveloped land was converted into residential land.

5.1.5 Comparison of Land Use Distribution Categories

To emphasize the dynamics of the watershed, Figure 21 shows the variation of temporal land use changes among all nine land use distribution categories over a 10 year period. In general, all categories experienced an overall decrease in agriculture, and all categories (except C2 and S2 - no change) experienced

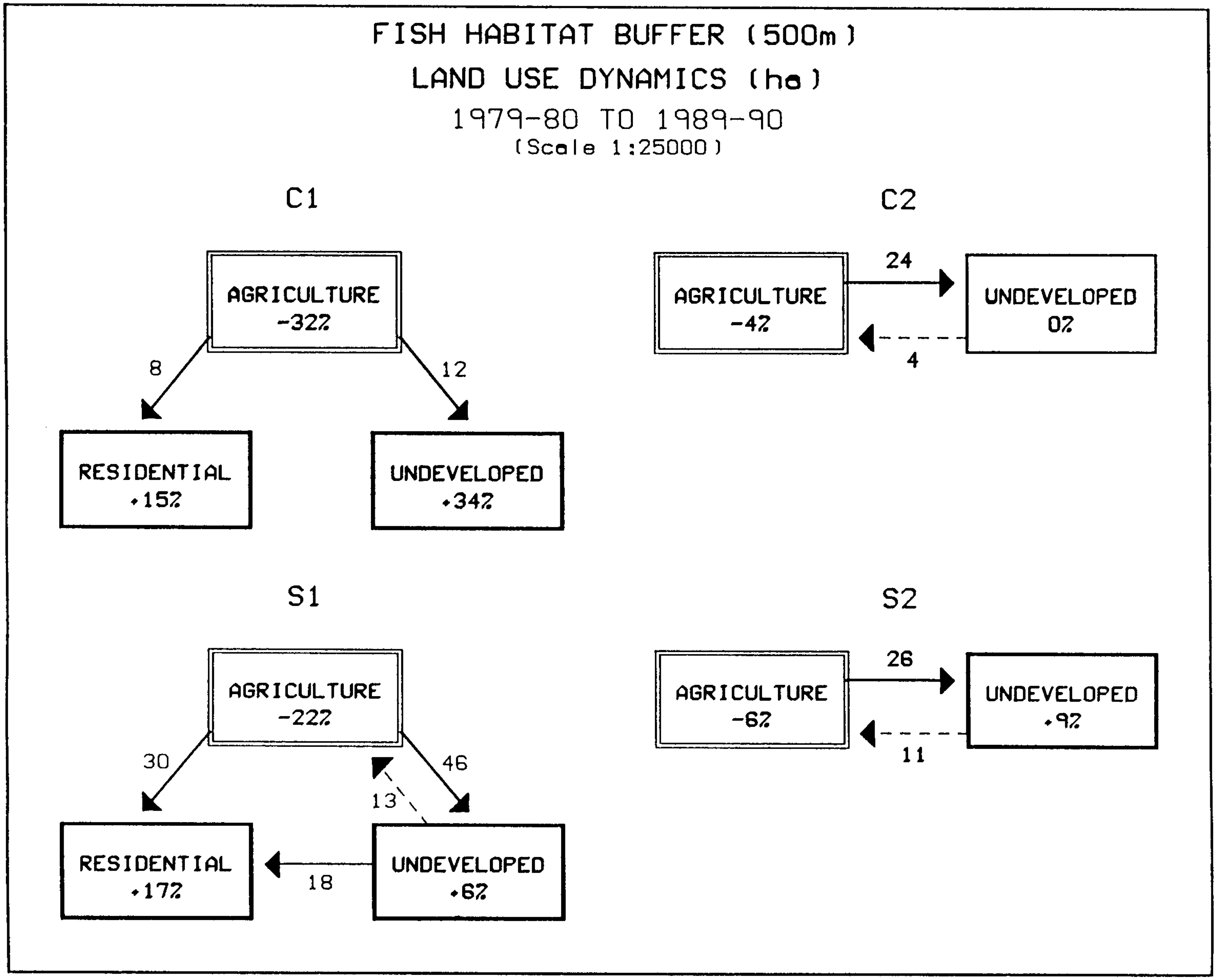


Figure 20. Changes in land use (ha) for buffered fish habitat reaches C1, C2, S1 and S2 - 1979-80 to 1989-90.

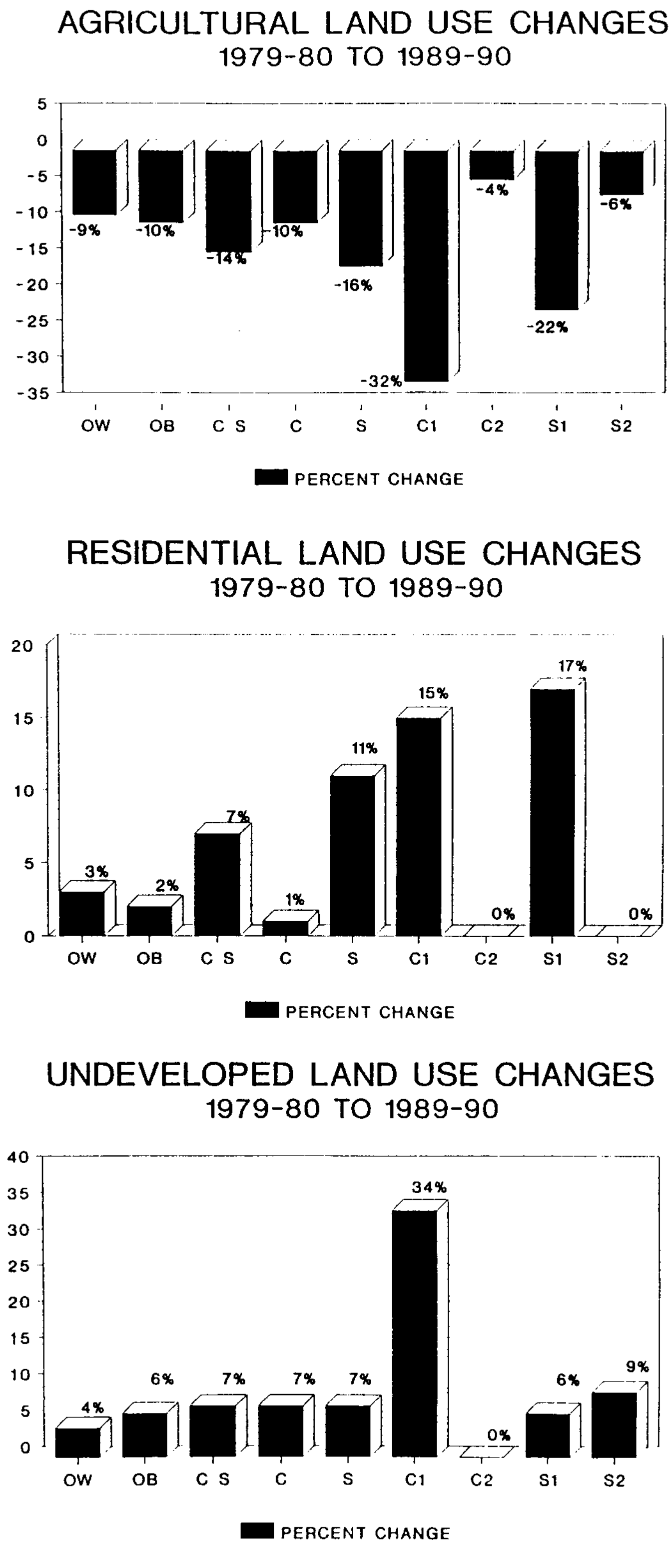


Figure 21. Comparison of all land use distribution categories in the Salmon River watershed showing temporal changes among agricultural, residential and undeveloped land use types - 1979-80 to 1989-90.

increases in both residential and undeveloped land. In most cases, the degree of change seems to intensify from large geographic areas to smaller ones for all 3 land use types. As previously discussed, the greatest potential for urban development seems to be within the habitat buffer of C1. The largest actual increase in residential development occurred in buffer segment S1.

5.1.6 Cumulative Analysis of Land Use Within Buffered Habitat Reaches

A detailed version of the 1989-90 land use pattern for all four buffered habitat reaches combined (CS) is illustrated in Figure 22. Crop production, livestock production, residential and undeveloped areas are the major land uses in this region. The total area of segment CS is approximately 673 ha. The Coghlan Creek (C) and Salmon River (S) buffered reaches have areas of 234 ha and 439 ha respectively.

Table 13 presents results from a cumulative evaluation of land use for 1989-90 which indicates how sensitive the Salmon River is to streamside land use compared to Coglan Creek. For each stream, the upstream habitat buffer (S2 and C2) is compared to both habitat buffers in each stream combined (S and C). Only land use types that occupy at least 9% of their respective segment (C or S) are used in the analysis.

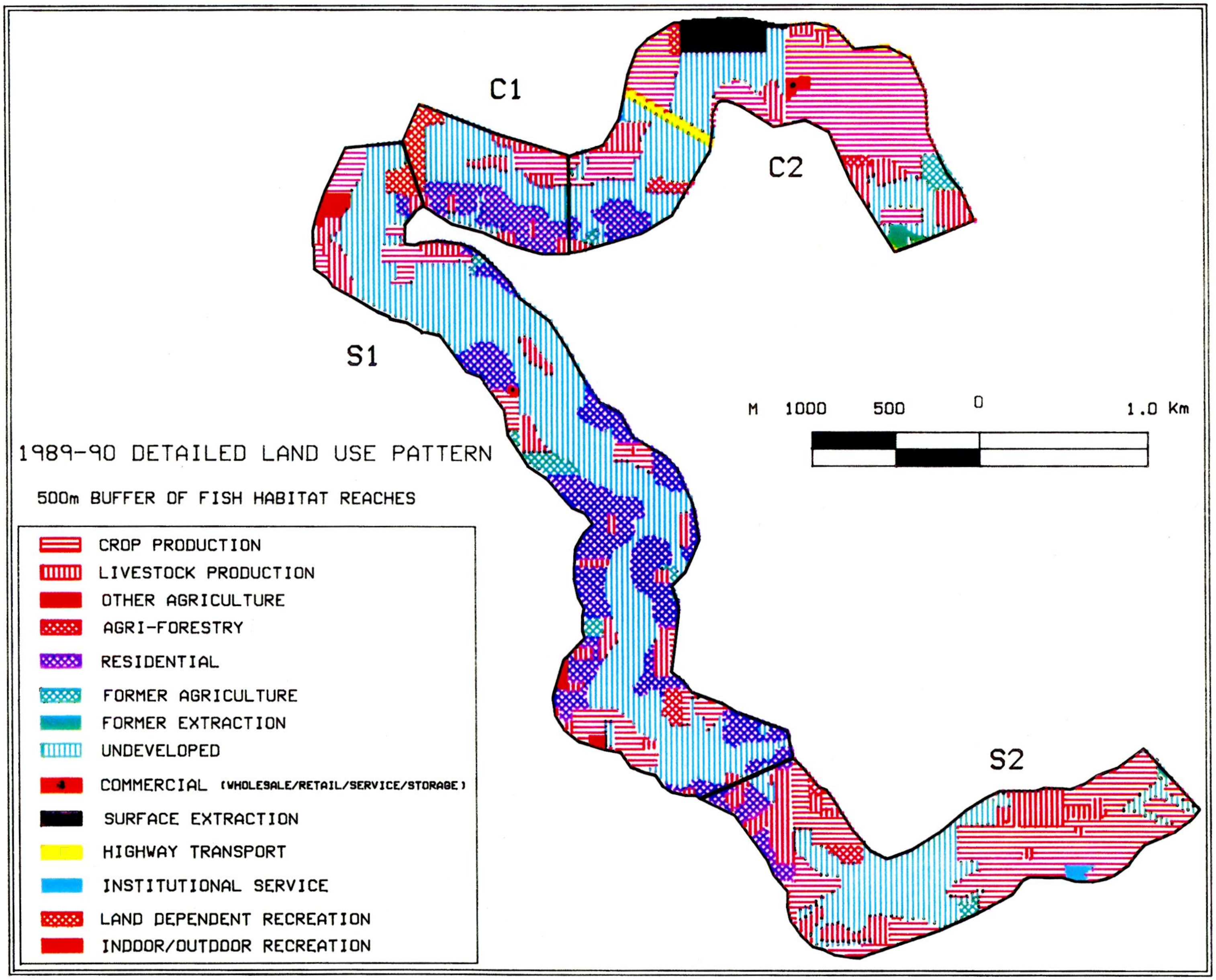


Figure 22. The 1989-90 detailed land use map of buffered fish habitat reaches in Coghlan Creek (C1 and C2) and the Salmon River (S1 and S2).

Table 13. Percent cumulative analysis of streamside land use (1989-90) comparing habitat study reaches in Coghlan Creek and the Salmon River.

Land Use	C2	C (C1+C2)	S2	S (S1+S2)
Crop Production	41	33	45	23
Livestock Production	10	10	17	11
Residential	3	9	4	16
Undeveloped	32	35	31	45

The overall trend for both streams reveals that crop production and livestock production decrease in intensity while residential and undeveloped areas increase in intensity from the upstream reaches to the lower reaches. Only livestock production in Coghlan Creek remained constant at 10%.

Cumulative land use trends for the Salmon River are quite dynamic. The results show that the magnitude of crop production drops by 22%, livestock production drops by 6%, residential increases by 12%, and undeveloped areas increase by 14%. Less striking results for Coghlan Creek show that the degree of crop production falls by 8%, livestock production remains constant at 10%, residential areas rise by 6%, and undeveloped areas rise by only 3%.

It is evident that the Salmon River is subject to far greater variability of land use intensities than Coghlan Creek. Specifically, the Salmon River is under more direct pressure related to urban development, but under less pressure from agricultural practices. This trend probably results from the fact that more undeveloped areas, conducive to residential development due to the nature of the topography, are found downstream in the Salmon River than in Coghlan Creek.

5.2 Fish Habitat Dynamics

The physical fish habitat data collected in 1980 and 1990 are associated with features of stream morphology, substrate composition, and salmonid cover requirements. The next four sections will discuss the results of the 1990 general survey conducted in Coghlan Creek and the Salmon River, outline the distribution of hydraulic units for 1990, contrast the fish habitat characteristics in 1980 to 1990, and outline how representative the 1990 detailed inventory is in relation to the general inventory for 1990.

5.2.1 Overall Survey of Hydraulic Units (1990)

The 1990 general survey documents all hydraulic units within designated reaches of Coghlan Creek and the Salmon River which provide important spawning and juvenile rearing habitat for salmonids. Table 14 shows the type and number of hydraulic units sampled. It is evident that riffles and glides are more numerous than pools and sloughs in this area of the watershed. The two objectives of this inventory were: a) to find out if each hydraulic unit type is unique; and b) to determine if there are differences between hydraulic units in Coghlan Creek and the Salmon River.

Table 14. Number of hydraulic units sampled in the 1990 general habitat survey.

Hydraulic Unit	Coghlan Creek	Salmon River	Total
Riffles	176	235	411
Glides	159	197	356
Pools	59	56	115
Sloughs	44	67	111

As shown in Table 15, all riffles, glides, pools and sloughs are significantly different from one another in terms of length, wetted width, depth, and general substrate characteristics. The only notable parameters that do not show significant differences are % boulder and volume between pools and sloughs, and area between glides and pools. None of the results contradict the expected differences in physical attributes between any of the four hydraulic units tested.

Table 15. Significant differences in length, wetted width (W.W.), area, depth, volume, and substrate composition parameters between hydraulic units. (Riffles = R, Glides = G, Pools = P, Sloughs = S)
note: Salmon River and Coghlan Creek hydraulic units combined.

	R v G	R v P	R v S	G v P	G v S	P v S
Length	*	*	*	*	*	*
W.W.	*	*	*	*	*	*
Area	*	*	*	-	*	*
Depth	*	*	*	*	*	*
Volume	*	*	*	*	*	-
% Fines	*	*	*	*	*	*
% Gravel	*	*	*	*	*	*
% Boulder	*	*	*	*	*	-

T-test * α=0.05

Summary statistics for the hydraulic units in Coghlan Creek and the Salmon River combined (CS) is presented in Table 16. Among the 4 types of hydraulic units, glides occupy the largest total area (16026 m^2) followed by riffles, sloughs and pools. Average depth is lowest in riffles (11 cm) and highest in pools (74 cm). Both riffles and glides on average contain the highest percentage of suitable gravel substrate for salmonid spawning purposes. The largest percentage of boulder substrate, a form of cover for juvenile salmonids, is found in riffles.

Table 17 shows significant differences in length, wetted width, area, depth, volume and substrate composition between hydraulic units in Coghlan Creek and the Salmon River. Similar hydraulic unit types between the two streams show some significant differences. In particular, Coghlan Creek sloughs are significantly different from sloughs in the Salmon River for most parameters. Several differences also exist between the two streams in terms of riffle and glide characteristics. For the pools, only depth and volume proved to be different.

Generally, the four hydraulic unit types are different from one another within each stream - the notable exceptions include: % boulder between Coghlan Creek riffles and pools; area and % boulder between Coghlan Creek glides and pools; length, area and % gravel between Coghlan Creek glides and sloughs; area, volume and % boulder between Coghlan Creek pools and sloughs; % gravel between Salmon River riffles and glides; length between Salmon River riffles and pools; area between Salmon River glides and pools; and volume, % gravel and % boulder between Salmon

River pools and sloughs.

Summary statistics that compare the hydraulic units in Coghlan Creek to the Salmon River are presented in Table 18. By taking the cumulative length of all hydraulic units in each stream, the Coghlan Creek study reach is approximately 5,319 m in length, and the Salmon River study reach is approximately 7,732 m in length. In general, the stream morphology characteristics for riffles, glides, pools and sloughs are larger in the Salmon River than in Coghlan Creek. This suggests that the Salmon River is somewhat larger in terms of its physical capacity to hold water. General substrate composition between the two streams for all four hydraulic unit types are quite similar. Riffles and glides in Coghlan Creek have slightly more gravel substrate than in the Salmon River but less boulder substrate. This would suggest that the potential for salmonid spawning is greater in Coghlan Creek, but the amount of cover for juvenile salmonids is greater in the Salmon River.

Table 16. Summary statistics for 1990 general habitat survey of hydraulic units. Coghlan Creek and Salmon River reaches combined (CS).

	LENGTH (m)	WETTED WIDTH (m)	AREA (m^2)	DEPTH (m)	VOLUME (m^3)	% FINES	% GRAVEL	% BOULDER
RIFFLES								
Mean	9.6	2.1	22.9	0.11	2.6	14	62	24
Standard Deviation	8.0	1.1	27.9	0.02	3.6	7	11	10
Minimum	1.0	0.5	0.5	0.05	0.1	10	10	0
Maximum	57.0	6.0	256.5	0.29	38.5	70	80	80
Total			9420.3					
GLIDES								
Mean	16.3	2.6	45.0	0.23	10.5	21	60	20
Standard Deviation	10.1	0.9	35.2	0.07	9.9	11	10	8
Minimum	2.0	0.5	2.0	0.10	0.2	10	20	0
Maximum	60.0	5.5	214.5	0.60	85.8	70	80	50
Total			16026.0					
POOLS								
Mean	8.3	4.8	42.2	0.74	36.3	40	45	16
Standard Deviation	4.2	2.2	37.4	0.38	50.0	13	11	9
Minimum	2.0	2.0	7.5	0.10	2.7	20	20	0
Maximum	22.0	20.0	300.0	2.50	390.0	70	70	60
Total			4851.0					
SLOUGHS								
Mean	21.1	3.7	82.7	0.39	36.0	33	51	15
Standard Deviation	24.5	2.8	137.8	0.15	71.2	12	12	6
Minimum	3.0	1.0	7.0	0.15	2.3	10	20	0
Maximum	220.0	30.0	1320.0	1.00	660.0	70	80	40
Total			9185.0					

Table 17. Significant differences in length, wetted width (w.w), area, depth, volume, and substrate composition parameters between hydraulic units (Riffles = r, Glides = g, Pools = p, Sloughs = s).
note: Salmon River (S) and Coghlan Creek (C) hydraulic units are differentiated.

	C-r v S-r	C-g v S-g	C-p v S-p	C-s v S-s
Length	-	-	-	**
W.W.	-	-	-	-
Area	-	-	-	**
Depth	**	**	**	**
Volume	-	-	**	**
% Fines	**	**	-	**
% Gravel	**	**	-	**
% Boulder	**	**	-	-

	C-r v C-g	C-r v C-p	C-r v C-s	C-g v C-p	C-g v C-s	C-p v C-s
Length	**	**	**	**	-	**
W.W.	**	**	**	**	**	**
Area	**	**	**	-	-	-
Depth	**	**	**	**	**	**
Volume	**	**	**	**	**	-
% Fines	**	**	**	**	**	**
% Gravel	**	**	**	**	-	**
% Boulder	**	-	**	-	**	-

	S-r v S-g	S-r v S-p	S-r v S-s	S-g v S-p	S-g v S-s	S-p v S-s
Length	**	-	**	**	**	**
W.W.	**	**	**	**	**	**
Area	**	**	**	-	**	**
Depth	**	**	**	**	**	**
Volume	**	**	**	**	**	-
% Fines	**	**	**	**	**	**
% Gravel	-	**	**	**	**	-
% Boulder	**	**	**	**	**	-

T-test ** α=0.05

Table 18. Summary statistics for the 1990 general habitat survey comparing hydraulic units in Coghlan Creek (C) to the Salmon River (S).

	LENGTH (m)	WETTED WIDTH (m)	AREA (m^2)	DEPTH (m)	VOLUME (m^3)	% FINES	% GRAVEL	% BOULDER
RIFFLES								
C-Mean	9.9	2.3	24.6	0.112	2.9	14.3	66	20
S-Mean	9.4	2.1	21.7	0.105	2.4	12.8	60	27
C-Stand. Deviation	7.3	1.2	26.7	0.03	3.6	7	11	11
S-Stand. Deviation	8.5	1.1	28.7	0.02	3.7	8	9	8
C-Minimum	1.0	0.5	1.0	0.05	0.1	10	10	0
S-Minimum	1.0	0.5	0.5	0.10	0.1	10	10	10
C-Maximum	40.0	6.0	180.0	0.29	25.2	40	80	80
S-Maximum	57.0	6.0	256.5	0.15	38.5	70	80	70
C-Total	1734.0		4326.3		504.3			
S-Total	2205.0		5094.0		556.4			
GLIDES								
C-Mean	15.4	2.7	42.0	0.235	10.0	22.4	61.1	17
S-Mean	17.1	2.6	47.4	0.218	11.0	19.3	58.6	22
C-Stand. Deviation	8.8	1.0	31.0	0.09	8.4	11	10	8
S-Stand. Deviation	11.0	0.9	38.2	0.05	10.9	11	10	7
C-Minimum	3.0	1.0	5.0	0.10	0.8	10	20	0
S-Minimum	2.0	0.5	2.0	0.10	0.2	10	20	10
C-Maximum	46.0	5.5	161.0	0.60	44.4	70	80	50
S-Maximum	60.0	5.5	214.5	0.40	85.8	70	80	40
C-Total	2442.5		6684.0		1592.7			
S-Total	3376.0		9342.0		2158.2			
POOLS								
C-Mean	7.9	4.6	38.9	0.55	23.2	38	45	17
S-Mean	8.7	5.0	45.6	0.95	50.1	41	44	15
C-Stand. Deviation	3.7	2.5	39.8	0.25	30.0	14	13	11
S-Stand. Deviation	4.6	1.8	34.6	0.40	62.1	12	10	7
C-Minimum	3.0	2.0	8.0	0.30	2.7	20	20	0
S-Minimum	2.0	2.0	7.5	0.10	4.0	20	30	10
C-Maximum	19.0	20.0	300.0	2.00	192.0	70	70	60
S-Maximum	22.0	13.0	160.0	2.50	390.0	60	70	30
C-Total	469.0		2296.8		1367.2			
S-Total	486.5		2554.3		2805.6			

Table 18. con't

	LENGTH (m)	WETTED WIDTH (m)	AREA (m^2)	DEPTH (m)	VOLUME (m^3)	% FINES	% GRAVEL	% BOULDER
SLOUGHS								
C-Mean	15.3	3.2	49.0	0.33	16.4	29	58	14
S-Mean	24.8	4.0	104.9	0.44	48.9	36	47	16
C-Stand. Deviation	9.3	1.3	37.7	0.11	16.0	11	12	8
S-Stand. Deviation	30.1	3.4	171.6	0.16	88.7	12	11	5
C-Minimum	5.0	1.0	7.0	0.15	2.5	10	20	0
S-Minimum	3.0	1.5	7.5	0.20	2.3	10	20	10
C-Maximum	50.0	6.0	225.0	0.75	99.0	70	80	40
S-Maximum	220.0	30.0	1320.0	1.00	660.0	70	70	20
C-Total	673.0		2158.0		721.9			
S-Total	1664.0		7027.0		3278.4			

5.2.1.1 Distribution of Hydraulic Units

The distribution of hydraulic units in terms of area and volume for reaches C1, C2, C, S1, S2 and S, are given in Table 19. In general, Coghlan Creek has a higher proportion of riffles and glides with respect to area and volume calculations than the Salmon River. Even the proportional area and volume of pools in Coghlan Creek are slightly higher than in the Salmon River. The actual total area and volume of riffles, glides and pools, however, are greatest in the Salmon River.

With respect to proportional differences between individual reaches within Coghlan Creek and the Salmon River, the volume of riffles is highest in C1, the volume of glides is highest in both C1 and C2, the volume of pools is highest in C2, and the volume of sloughs is highest in S2. The actual total volume of riffles, glides, and pools is greatest in S1, primarily due to its sheer size relative to the reaches found in Coghlan Creek. Reach S2 has the highest volume in sloughs.

Table 19. Hydraulic unit distributions in area (m^2) and volume (m^3) for C1 and C2 in Coghlan Creek (C) and S1 and S2 in the Salmon River (S).

	C1	% of C1	C2	% of C2	C	% of C	S1	% of S1	S2	% of S2	S	% of S
AREA (m^2)												
Riffles	1947.0	(32)	2379.3	(25)	4326.3	(28)	4302.5	(25)	791.5	(11)	5094.0	(21)
Glides	2523.5	(41)	4160.5	(45)	6684.0	(43)	7776.0	(46)	1566.0	(23)	9342.0	(39)
Pools	898.3	(15)	1398.5	(15)	2296.8	(15)	1858.3	(11)	696.0	(10)	2554.3	(11)
Sloughs	727.0	(12)	1431.0	(14)	2158.0	(14)	3155.5	(18)	3871.5	(56)	7027.0	(29)
Total Area	6095.8		9369.3		15465.1		17092.3		6925.0		24017.3	
VOLUME (m^3)												
Riffles	238.7	(15)	265.6	(10)	504.3	(12)	474.4	(9)	82.0	(2)	556.4	(6)
Glides	593.4	(38)	999.4	(38)	1592.8	(38)	1798.6	(33)	359.6	(11)	2158.2	(25)
Pools	445.6	(29)	921.6	(35)	1367.2	(33)	1784.8	(32)	1020.8	(31)	2805.6	(32)
Sloughs	282.5	(18)	439.4	(17)	721.9	(17)	1443.8	(26)	1834.6	(56)	3278.4	(37)
Total Volume	1560.2		2626.0		4186.2		5501.6		3297.0		8798.6	

The amount and distribution of hydraulic units can be a good indicator of preferred habitat for different species of salmonids. Hartman (1965) examined the differences in micro-distribution between juvenile coho salmon and trout (steelhead and cutthroat trout) in Coghlan Creek and the Salmon River. The study suggests that in spring and summer, when population densities are high, coho salmon occupy pools and trout occupy riffles. Hartman emphasized these findings again in 1968. Based on this information and correlating it with Table 19, the density of juvenile coho salmon would be highest in reach C2, and the density of steelhead and cutthroat trout would be highest in reach C1. The total number of coho salmon and steelhead and cutthroat trout might be highest in reach S1.

5.2.2 Comparison of Temporal Changes in Fish Habitat (1980/1990)

Changes in physical fish habitat from 1980 to 1990 are categorized into 3 major groups; i) stream morphology, ii) substrate composition, and iii) cover requirements. Stream discharge and stream temperature are also contrasted between years. The physical fish habitat parameters are compared for 3 types of hydraulic units (riffles, glides and pools) in stream reaches C1, C2, S1 and S2.

Stream morphology characteristics of length, wetted width, area, depth, volume and channel width, are compared in Figure 23. General trends for the study area and the dynamic temporal changes are highlighted below:

Area (from 1980 to 1990)

- Riffle area increases - particularly in reach S1 (exceptions: riffles in S2).
- Glide area increases - particularly in reach C2 and S1 (exceptions: glides in C1)
- Pool area decreases - particularly in reach C1 and S2 (exceptions: pools in C2).

Volume (from 1980 to 1990)

- Riffle volume increases (exceptions: riffles in S2)
- Glide volume increases (exceptions: glides in C1)
- Pool volume decreases in C1 - particularly in reach S2; and

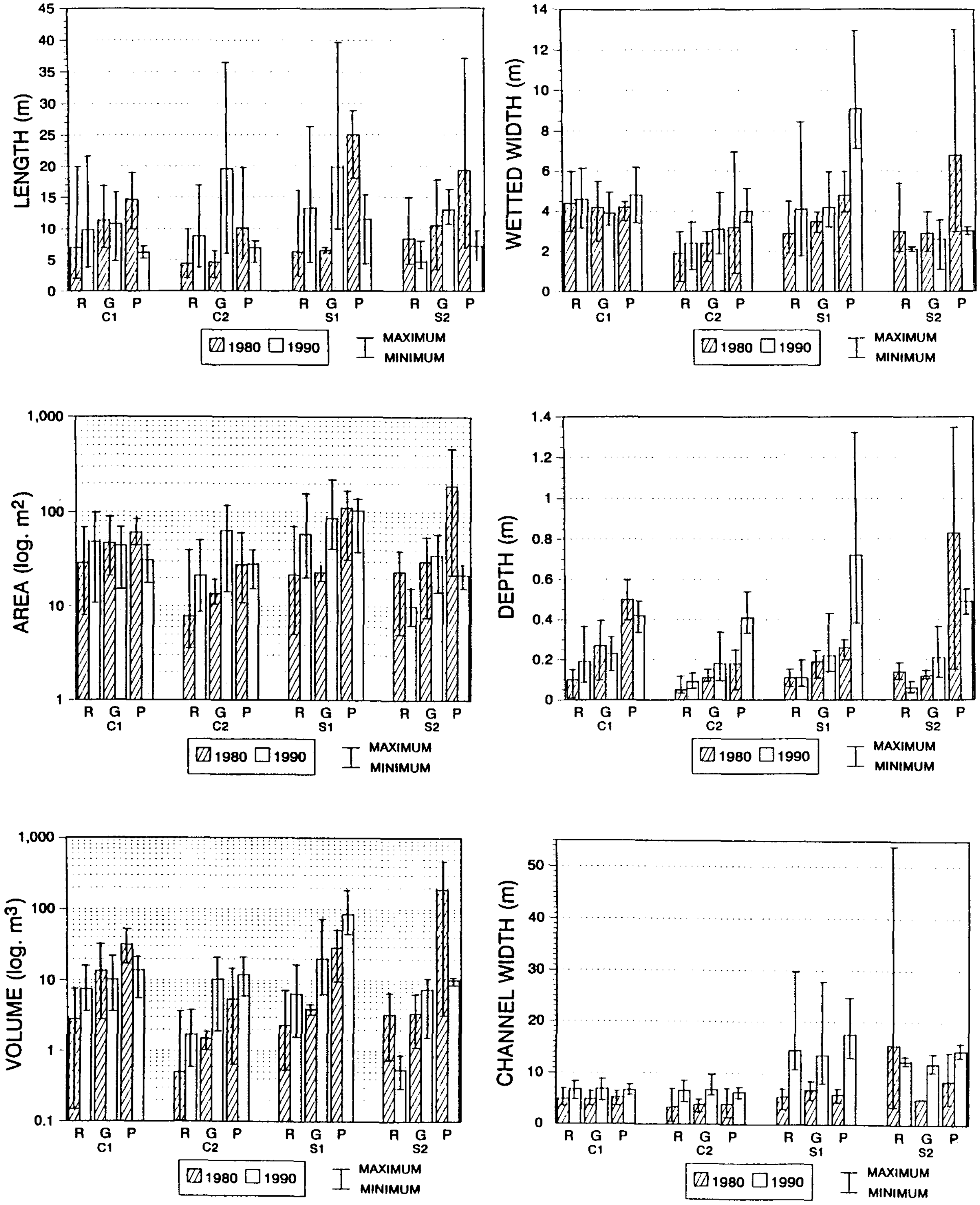


Figure 23. Comparison of stream morphology characteristics in 1980 and 1990. Mean, maximum and minimum variations between riffles (R), glides (G) and pools (P), are shown for reaches C1, C2, S1 and S2.

increases in C2 - particularly in reach S1.

Riffle and glide hydraulic units are preferred habitat during the summer months for juvenile steelhead trout (probably cutthroat trout as well), whereas pools are preferred habitat for coho salmon (Hartman, 1965, 1968; Pearlstone, 1976; Ward and Slaney, 1979; Reeves, et al., 1989). The above temporal trends for area and volume suggest that preferred riffle/glide habitat for juvenile trout may have increased over 10 years, particularly in reaches C2 and S1. Preferred pool habitat for juvenile coho salmon may have decreased in C1 and S2, but increased in C2 and S1.

Note: Sloughs may have been identified as pools in 1980 which might account for a decrease in pool area in 1990.

Depth (from 1980 to 1990)

- Riffle depth increases (exceptions: riffles in S2)
- Glide depth increases (exceptions: glides in C1)
- Pool depth increases in reach C2 and S1; and decreases in reach C1 and S2.

According to Pearlstone (1976) and Ward and Slaney (1979), most juvenile steelhead trout rear during the summer months in depths that range from 0.20 to 0.50 meters. Temporal trends for the study area suggest that most riffle and glide depths had increased slightly - closely resembling the lower limit of the preferred range as mentioned above. On the other hand, the results in 1980 are mostly below 0.20 meters. In general, preferred depth conditions for rearing juvenile steelhead trout might have improved over the 10 year period.

Channel Width (from 1980 to 1990)

- Riffle channel width increases (exceptions: reach S2)
- Glide channel width increases
- Pool channel width increases

Channel width associated with all 3 hydraulic unit types increases in all cases from 1980 to 1990. This increase is probably the result of several high instantaneous discharge events that took place over the 10 year period [eg. 32.9 $m^3 s^{-1}$ in 1980, 61.4 $m^3 s^{-1}$ in 1986, and 35.9 $m^3 s^{-1}$ in 1989 (Environment Canada, 1991)]. Increased impervious areas as a result of urbanization might also be contributing to higher discharge rates and widening of the stream channel.

Figure 24 compares substrate composition (% fines, % small gravel, % large gravel, % cobble and % boulder) between 1980 and 1990 for the hydraulic units in each stream reach. Given the subjective nature of this kind of assessment, only the extreme differences in temporal trends are highlighted below.

% Fines (from 1980 to 1990)

- For riffles, a large increase is noted in reach S2.
- For pools, a large increase is evident in S2; and a large decrease is apparent in reach C1.

% Small Gravel (from 1980 to 1990)

- For pools, a substantial increase occurs in reaches C1 and C2.

% Large Gravel (from 1980 to 1990)

- For riffles, a large decrease is evident in reach S2.
- For glides, a large decrease occurs in reach S1.

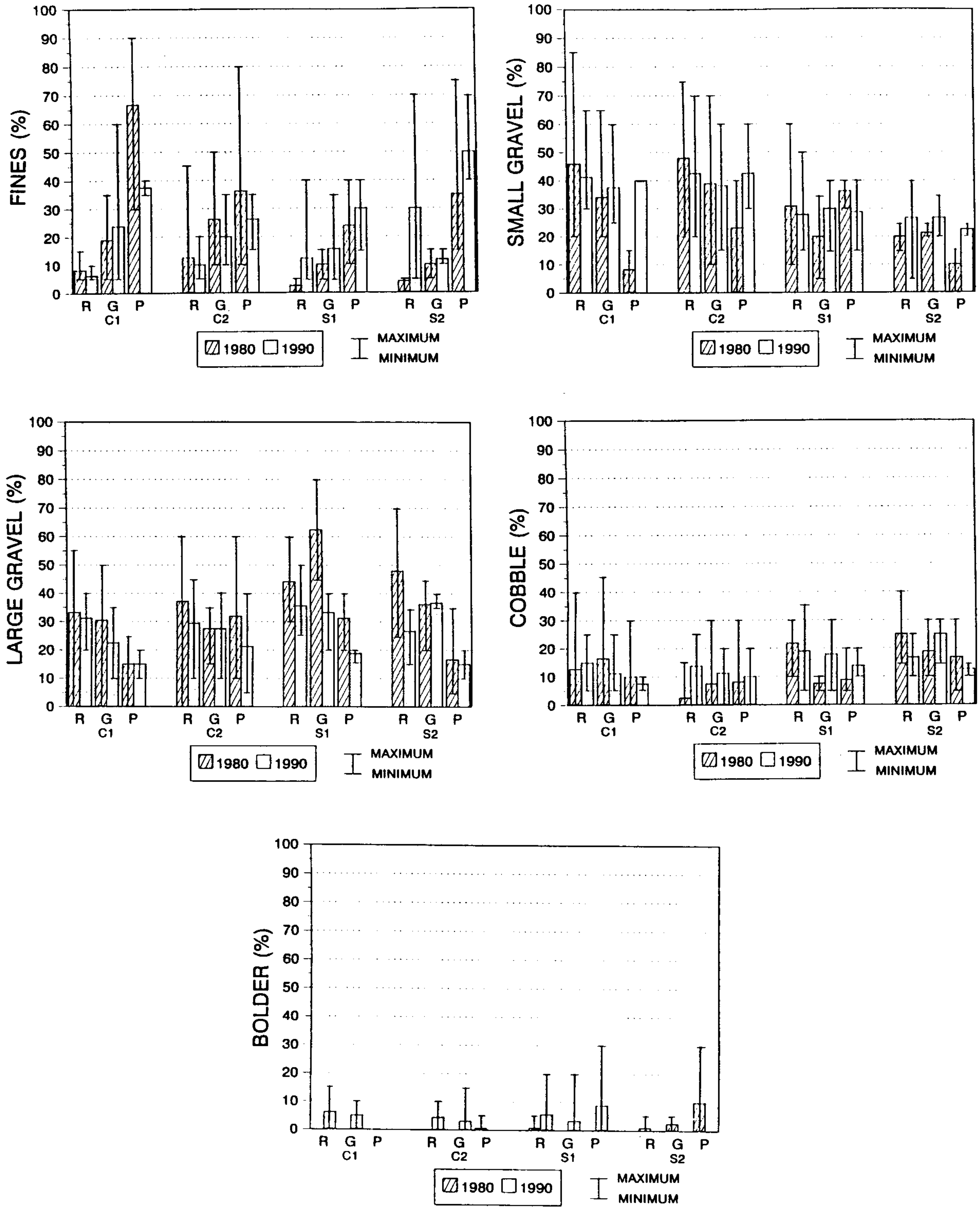


Figure 24. Comparison of percent substrate composition in 1980 and 1990. Mean, maximum and minimum variations between riffles (R), glides (G) and pools (P), are shown for reaches C1, C2, S1 and S2.

% Cobble

- No significant changes noted.

% Boulder

- No significant changes noted.

According to Pearlstone (1976), 0+ steelhead trout in the Big Qualicum River inhabit areas over substrate ranging from 1-10 cm in diameter, and 1+ fish reside over substrate from 5-20 cm in diameter. Optimum spawning substrate for steelhead trout ranges from 0.6-10 cm in diameter (Swift, 1976); whereas preferred spawning substrate for coho salmon ranges from 1-20 cm in diameter (Reeves, et al., 1989). If these substrate criteria for rearing and spawning activities are correlated with the substrate categories defined by Deleeuw (1981), the following inferences can be made with respect to temporal changes in substrate composition:

a) Steelhead trout rearing and spawning habitat has possibly declined in reach S2 because of high increases in % fines and large decreases in % large gravel. For the same reasons, suitable spawning grounds for coho salmon have possibly declined in reach S2 as well.

b) Suitable rearing substrate for age 0+ steelhead has possibly improved in reaches C1 and C2 due to high increases in % small gravel.

Changes in characteristics of cover requirements (instream log, instream boulder, instream vegetation, overstream vegetation and cuttbank) between 1980 and 1990 are shown in Figure 25. The general trends and extreme temporal changes are

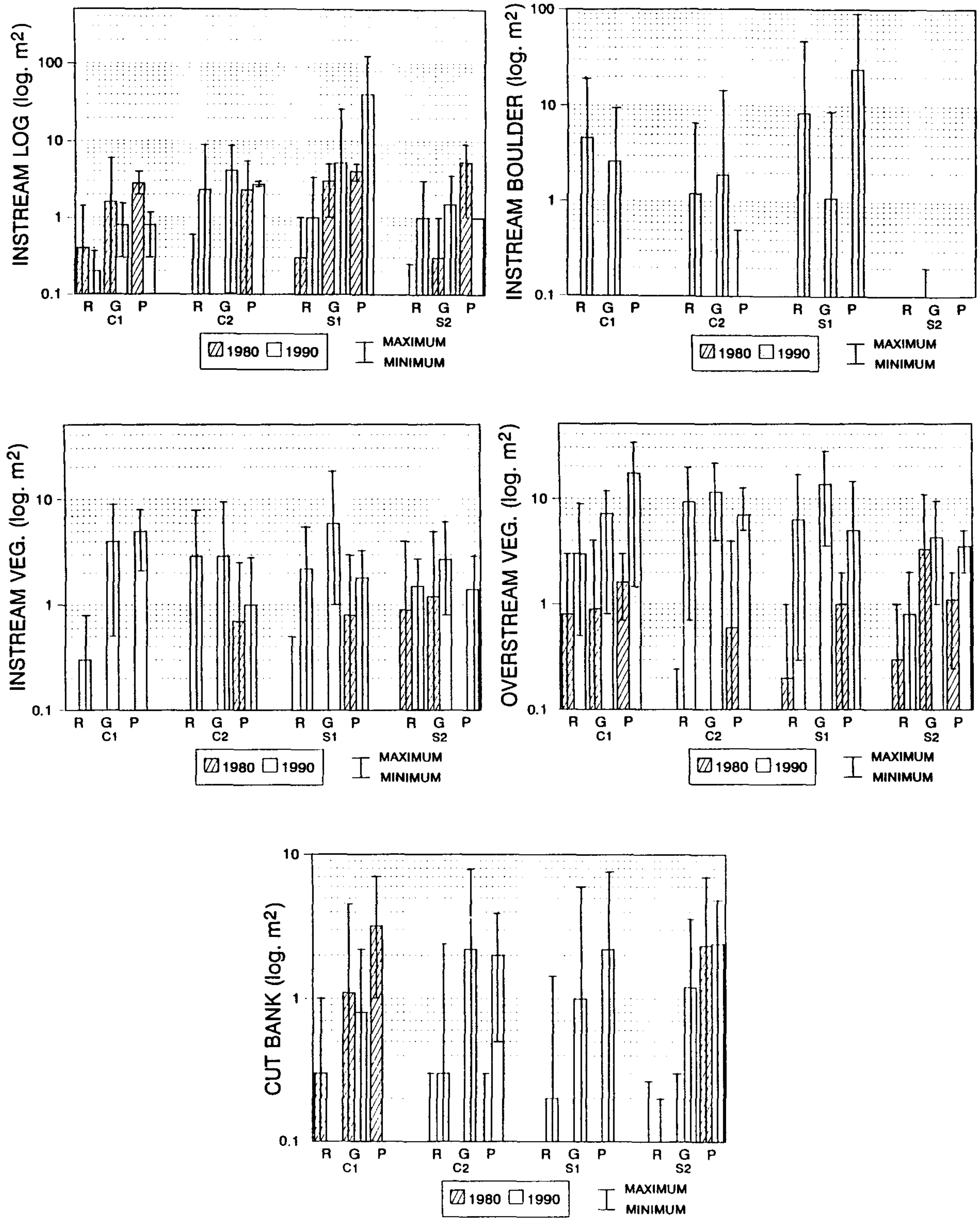


Figure 25. Comparison of salmonid cover requirements in 1980 and 1990. Mean, maximum and minimum variations between riffles (R), glides (G), and pools (P), are shown for reaches C1, C2, S1 and S2.

listed below.

Instream Log (from 1980 to 1990)

- For riffles, the amount of instream log increases (exceptions: reach C1).

- For glides, the amount of instream log increases (exceptions: reach C1).

- For pools, the amount of instream log increases in C2 - particularly in reach S1; and decreases in C1 and S2.

Instream Boulder (from 1980 to 1990)

- For riffles and glides, the amount of instream boulder increases in C1, C2 and S1 (no significant amount recorded in S2 for either year).

- For pools, a significant increase in the amount of instream boulder is evident in reach S1 (no significant amount recorded in C1, C2, or S2 for either year).

Instream Vegetation (from 1980 to 1990)

- For riffles, glides and pools, the quantity of instream vegetation increases in all 4 reaches.

Overstream Vegetation (from 1980 to 1990)

- For riffles, glides and pools, the amount of overstream vegetation increases in all 4 reaches - particularly glides in reach S1 and pools in reach C1.

Cutbank (from 1980 to 1990)

- For riffles, glides and pools, the area of cutbank increases in all reaches except C1.

The quality and quantity of large woody debris, boulder groupings and streamside vegetation, appear to be major factors governing the survival of juvenile salmonids throughout the summer and winter rearing seasons (e.g. Pearlstone, 1976; Facchin and Slaney, 1977; Hunter, 1991).

For juvenile steelhead trout (1+) and coho salmon, stable instream log debris is a major component of winter and summer cover (Bustard and Narver, 1975; Pearlstone, 1976; Ward and Slaney, 1979; Reeves et al., 1989). Temporal trends for the study area suggest that a large increase in pool log debris occurred in reach S1 - probably the result of blow down effects of old-aged coniferous trees, particularly in steeply sloped areas. The increase in pool log debris would greatly benefit rearing coho salmon during the summer, and both coho salmon and steelhead trout (probably cutthroat trout as well) during winter rearing periods. One area of concern is the overall decrease of log debris in reach C1. Because a large area of reach C1 is within a "well kept" municipal park (Williams Park), it is possible that much of the stream-side vegetation (including coniferous and deciduous trees) has been removed for aesthetic and human safety reasons. This removal of vegetation limits the natural inputs of large organic material into the stream which in turn impacts salmonid cover requirements.

Groups of boulders are utilized by both steelhead trout and coho salmon as an important source of summer and winter cover (Bustard and Narver, 1975; Facchin and Slaney, 1977; Ward and Slaney, 1979; Reeves, et al., 1989). In reach S1 of the study area, the amount of instream boulders in pools increased substantially from 1980 to 1990. This trend in S1 suggests that summer habitat conditions for rearing coho salmon and winter habitat for trout and coho salmon improved. Virtually no boulder cover for salmonids was apparent in 1980 or 1990 in reach S2. Stream rearing enhancement opportunities in the form of boulder placement would be beneficial to rearing salmonids in this reach. [Note: Methods of instream boulder measurements in 1990 were not consistent with measurements taken in 1980 (i.e. a group of 2-3 boulders was considered sufficient cover for juvenile salmonids in 1990, but was not in 1980)].

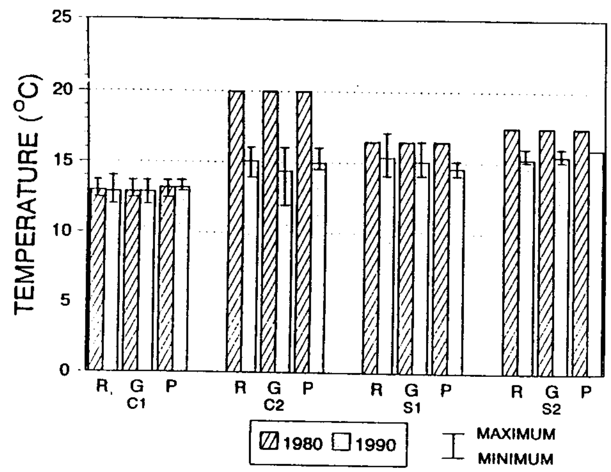
Streamside vegetation plays an integral part in moderating stream temperatures and providing cover and food sources for juvenile salmonids (Bustard and Narver, 1975; Anonymous, 1980). This type of habitat (overstream vegetation) increased considerably over 10 years for pools in reach C1 and glides in reach S1. Coho salmon would probably benefit most during the summer rearing period in reach C1; whereas trout would benefit most in reach S1.

A large portion of the cutbank area measured in the study area provides good summer rearing cover (and possibly winter cover) for juvenile salmonids (personal observation, 1990). According to Bustard and Narver (1975), coho salmon and cutthroat trout prefer hydraulic units with overhanging stream banks as opposed to those without bank cover. The increase in cutbank area for reaches C2, S1 and S2 likely benefit coho salmon and trout in the summer and perhaps ever during the winter. The slight increase in cutbank area in these 3 reaches is probably related to the number of high instantaneous discharge events as discussed earlier in this section. Of considerable concern is the decrease in cutbank area in reach C1 which has likely impacted the summer and potential winter rearing opportunities for salmonids. The reduction in cutbank area is likely due to rip-rap and gabion placement along the stream banks in Williams Park. This enhancement work was done in the early 1980's, primarily to stabilize stream banks and to prevent erosion at high flows.

Temporal changes in average discharge rates and stream temperatures for each reach are presented in Figure 26. Discharge rates increased over a 10 year period in Coghlan Creek, while rates decreased in the Salmon River, particularly in reach S1. Specifically, S1 experienced a 50% decrease in flow from 1980 to 1990; a trend likely due to increases in water withdrawals for purposes of land improvement, irrigation, and domestic use (unpublished data from Ministry of Environment, Lands and Parks, 1991).

Based on recommendations from Thompson (1972), minimum flow requirements for rearing salmonids is approximately 1.4 m^3s^{-1}. All four reaches in Coghlan Creek and the Salmon River are well below this recommended minimum flow regime.

The average stream temperature in 1990 was cooler than in 1980 for most reaches. Only reach C1 had temperatures that were similar for both years. Reeves (1989) notes that if stream temperatures exceed 20°C for two weeks or more during summer low flows, production of pre-smolts might be limited due to less favourable environmental conditions or by conferring advantage



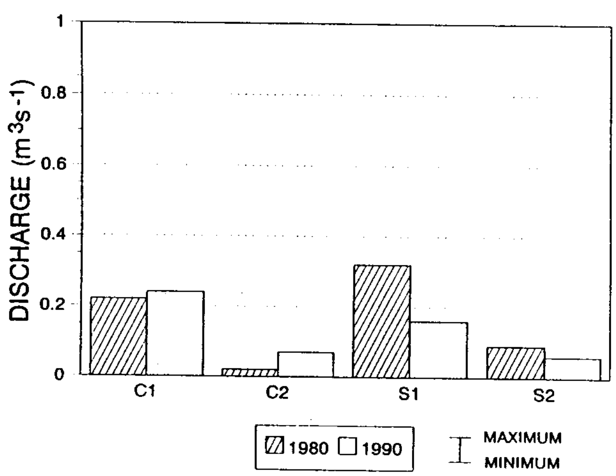


Figure 26. Comparison of stream temperature and stream discharge in 1980 and 1990. For temperature, the mean, maximum and minimum variations between riffles (R), glides (G) and pools (P), are shown for reaches C1, C2, S1 and S2. Only the mean for each reach is shown for discharge.

to non-salmonid competitors. Only reach C2 in 1980 had temperatures that were around 20°C; a temperature that is also close to the upper avoidance level for most salmonids. Generally, juvenile salmonids prefer to rear in temperatures from 12°C to 14°C (Brett, 1952; Toews and Brownlee, 1981; Chilibeck et al., 1992).

5.2.2.1 Representation of the 1990 Detailed Inventory to the Overall Survey

Only general temporal trends of fish habitat could be depicted in section 5.2.2 because of experimental design problems associated with the data sets in 1980 and 1990.

Table 20 shows significant differences in length, wetted width, area, depth and volume characteristics among similar hydraulic unit types in the 1990 general survey and selected hydraulic units which form the detailed inventory. It is evident that many of the parameters measured in each of the two survey's are different, both in Coghlan Creek and the Salmon River. This analysis indicates that the selected hydraulic units chosen for the detailed analysis do not adequately represent the characteristics of stream morphology in the study area. It is apparent that the physical parameters associated with each type of hydraulic unit are highly variable, not only between reaches but also within each reach. In order to obtain a more accurate and representative sample, a larger number of hydraulic units of each type would need to be inventoried from the general survey. [Note: Between 5.1% and 13.6% of each hydraulic unit type was sampled from the general survey in C and the S to form the detailed inventory.]

The 1980 data set is probably less representative of the actual physical fish habitat conditions for that time period than the 1990 data set. A general survey was not conducted in 1980 to establish an information base line, and site selection was based on non-random methodologies related mainly to accessibility.

Table 20. Significant differences in length, wetted width, area, depth and volume between hydraulic units sampled in the 1990 general survey and random samples taken for the 1990 detailed inventory (Riffles = r, Glides = g, Pools = p, Sloughs = s).
note: Salmon River (S) and Coghlan Creek (C) hydraulic units are differentiated.

General Survey v Detailed Inventory	C-r v C-r	S-r v S-r	C-g v C-g	S-g v S-g
Length	-	-	-	-
Wetted Width	**	**	**	**
Area	-	**	-	*
Depth	*	**	*	-
Volume	-	**	-	-

General Survey v Detailed Inventory	C-p v C-p	S-p v S-p	C-s v C-s	S-s v S-s
Length	-	-	-	**
Wetted Width	-	-	-	**
Area	-	-	-	**
Depth	**	**	-	-
Volume	-	-	-	**

Mann-Whitney U test ** α=0.05, * α=0.10

5.3 Land Use and Fish Habitat Trends

This section discusses land use and fish habitat trends while examining land use dynamics within the buffered habitat reaches in conjunction with the distribution of hydraulic units measured in 1990. To provide some linkage between land use and fish habitat, the effects of urbanization on water quantity, stream channel alteration, and water quality are reviewed. Also, fish production between Coghlan Creek and the Salmon River are compared and related to fish habitat.

5.3.1 Water Quantity, Stream Channel Alteration, and Water Quality

McPherson (1974) states: "the impact of man on the water cycle is greatest per unit area in urban places". Many studies have shown that urbanization has had significant influences on stream channel morphology as well as the quality and quantity of water that flows through a watershed (Oltmann and Shulters, 1989; Osborne and Wiley, 1988; Whipple et al., 1983; Sylvester and Brown, 1978; Lazaro, 1979; and Stamer, et al. 1979)

Urbanization usually means a change in landscape from a natural state to a more impervious environment (e.g. concrete surfaces) which most often alters surface water flows. In short, an urbanized "stream system" with large impervious areas will react more swiftly to rainfall and will flood more rapidly than a forested or otherwise undeveloped watershed. These processes will result in steeper rising and falling hydrograph limbs, and higher peak flows. Moreover, large impervious areas decrease infiltration rates which can reduce baseflows during the summer months. Studies that show the influences of urbanization on the quantity of water with specific reference to streamflow are found in Oltmann and Shulters (1989); Whipple et al. (1983); Swain et al. (1983); and Sylvester and Brown (1978).

Changes in stream channel morphology as a result of increased channelization and stream diversions are prevalent in many urban watersheds. Extension of urban development and channelization, particularly in upstream reaches, can negatively affect fish production through habitat loss as well as to produce flooding problems associated with accelerated runoff (Fisheries and Oceans, 1983). The installation of culverts also contributes to stream channelization (Dane, 1978; Toews and Brownlee, 1981).

The water quality of streams is related to water quantity (surface and subsurface runoff), the geology through which a stream flows, the climatic and geologic histories of the region, and the land use inputs from point and non-point sources. When runoff has higher concentrations of constituents than normal, the water quality balance of the stream system may be upset (Lazaro, 1979). Many studies have shown that residential/urban areas generate significantly higher pollutant loadings compared to other land uses (Osborne and Wiley, 1988; Stamer, et al. 1979; Dever, et al. 1979; Sylvester and Brown III, 1978). Many of these pollutants may taint fish to the extent that they become either unpalatable or unsafe for human consumption. Pollutants can also exert sub-lethal effects on fish by reducing the amount of food organisms, lowering the level of dissolved oxygen, and by placing fish under stress which has the overall effect of discouraging fish from populating otherwise good habitat (Fisheries and Oceans Canada, 1983).

The groundwater in many watersheds is largely responsible for supplying flow to streams during the summer months. Recent studies by Liebscher, et al. (1992) and Gartner Lee (1992) have found significant levels of nitrates and pesticides in local groundwater reservoirs stemming from agricultural activities and rural residential septic systems.

Stormwater runoff is probably the most widely recognized contributor to water quality problems in urban watersheds. A wide variety of contaminants have been found in urban stormwater and concentrations of these contaminants can be quite variable (Swain, 1983; Roesner, 1982; Duda et al., 1979; Koch et al., 1977). Mills (1977) sampled stormwater runoff and recorded extremely high concentrations for suspended solids, dissolved solids, total solids, conductivity, sodium, chloride, sulphate, lead, alkalinity, hardness and nitrate. Koch et al. (1977) noted that residential wastewaters appear to be a major source of copper, and to some extent lead and zinc, in municipal sewage. Swain (1983) found that constituents such as suspended solids, total and fecal coliforms, aluminum, copper, lead and zinc were proportional to flow in a residential catchment area. It is generally recognized that the "first flush" of a storm event seems to produce the highest concentration of contaminants in stormwater runoff (Chilibeck et al., 1992; Schreier et al., 1991; Stamer et al., 1979; Howell, 1979; Sylvester and Brown, 1978).

Siltation, although traditionally treated as an aspect of water quality is closely interrelated with both water quantity and stream channel alterations. Within urban areas, increases in storm runoff add high peaks of energy which augment the natural erosive forces and greatly accelerate erosion. Streams are filled with sediment-laden water, and their cross sectional areas may be enlarged (Hammer, 1972). Erosion and sediment can have severe negative impacts on all life stages of fish and their habitat. Suspended sediment can: a) settle on spawning areas, infill the intergravel voids and smother the eggs and alevins in the gravel; b) clog and abrade fish gills, causing suffocation or injury to fish; c) reduce water clarity and visibility in the stream, impairing the ability of juvenile fish to find food items; and d) settle and smother and displace aquatic organisms (benthic invertebrates), reducing the amount of food items available to fish (Chilibeck, 1992). In addition, bed load and settled sediments can infill pools and riffles, reducing the availability and quality of rearing habitat for fish, and increased levels of sediment can displace fish out of prime habitat into less suitable areas (Fisheries and Oceans Canada, 1983).

5.3.2 Fish Production and Fish Habitat in Coghlan Creek and the Salmon River

As suggested in section 5.2.1.1, the proportional area and volume of riffles, glides and pools (preferred hydraulic fish habitat) is higher in Coghlan Creek than in the Salmon River. However, the actual amount of potentially good hydraulic habitat is greatest in the Salmon River. The total volume of the Salmon River is about twice that of Coghlan Creek (Table 21).

Table 21. Comparison of coho salmon and trout (cutthroat and steelhead) smolt catches in Coghlan Creek and the Salmon River for 1979, 1980, and 1987-1992 (Schubert, 1982; Schubert, 1992). Also, total volume (m^3) of preferred hydraulic habitat for salmonids (riffles, glides, pools) in Coghlan Creek and the Salmon River (1990).

	COGHLAN CREEK			SALMON RIVER		
	Coho	Trout	Total	Coho	Trout	Total
*1979	14709	942	15651	27566	1529	29095
*1980	12206	2118	14324	21502	3604	25106
*1987	8476	1082	9558	15572	3231	18803
*1988	9949	2791	12740	17142	1919	19061
*1989	13568	2128	15696	25649	3567	29216
*1990	13265	3652	16917	9904	1745	11649
**1991	10667	2484	13151	24346	2392	26738
*1992	17140	2082	19222	17361	1371	18732

* Traps inoperable for 3 to 8 days due to high flows
** Only year where traps were operable for entire trapping period (April 22 - May 30)

note: (a) peak smolt outmigration occurs during high flow conditions
(b) data not available from 1981 to 1985
(c) 1986 data unreliable due to trap problems.

1990 HYDRAULIC HABITAT	COGHLAN CREEK	SALMON RIVER
Volume	3463 m^3	5520 m^3
Percent of Stream	(83%)	(63%)
STREAM REACH VOLUME	4186 m^3	8799 m^3

Table 21 also shows 1979, 1980, and 1987-1992 coho salmon and trout smolt catches for Coghlan Creek and the Salmon River. Collection of smolts was facilitated by the use of fish traps (described by Schubert, 1982) operated by Department of Fisheries and Oceans staff. The intention of the smolt capture program was to conduct a coded wire tag assessment of coho salmon. Each trap (one in Coghlan Creek and another in the Salmon River) was constructed not more than 100 meters above the confluence in each stream for the above mentioned years. Both traps were operated during the smolt outmigration period from mid April to early June (peak smolt outmigration occurred between May 1 and May 15 at high flow for all trap years). The field work was not intended to assess the true size or timing of smolt outmigration, however, the number of smolts caught may indicate relative fish production over time between the two streams (Schubert, 1992).

Smolt catch records from 1979 to 1989 (with the exception of trout in 1988), suggest that both coho salmon and trout production is higher in the Salmon River than in Coghlan Creek. This trend is likely associated with the large volume of good hydraulic habitat and total stream reach volume found in the Salmon River. It is apparent in Table 21 that both smolt production (particularly coho salmon) and stream reach volume for Coghlan Creek and the Salmon River show a consistent 1:2 ratio from 1979 to 1989 (note: "hydraulic habitat" is only one of many factors which influence the production of smolts). The ratio is fairly consistent in spite of year by year fluctuation in fish numbers suggesting that the habitat classification used might be a good reflection of fish production.

A 1:2 ratio between Coghlan Creek and the Salmon River is also evident for smolt catch records and stream volume in 1991, however, this was the only year in which traps were operable during high flow conditions. Peak smolt outmigration usually occurs during high flow conditions (Kalnin, 1992).

For 1990, smolt production in the Salmon River substantially decreases by about half with about 5000 fewer smolts than Coghlan Creek. In 1992, the number of smolts caught are about equal. It is possible that the effects of land use and land use change on stream flow and water quality could be responsible for this decline. However, additional sampling is needed to confirm this trend.

5.3.3 Dynamics of Land Use and Land Use Change in Relation to Buffered Fish Habitat Reaches

In section 5.1.5 (see Figure 21), it was noted that the Salmon River land use buffer (particularly buffer S1) incurred the largest increase in residential development from 1979-80 to 1989-90. Presumably, much of this development took place during the later two to three years and might partially explain the apparent decline in fish production starting in 1990. With a 16% loss in agriculture and a 7% increase in undeveloped land, it is evident that urbanization will probably continue in the Salmon River.

The greatest potential for urban development is within the Coghlan Creek land use buffer (particularly buffer C1) where in proportional terms, there is more preferred hydraulic habitat for salmonids than in the Salmon River. If intensive urban activities are carried out in close proximity to Coghlan Creek as they were in the Salmon River, fish production may also decline substantially.

In terms of individual land use buffer segments for each stream, the most dynamic temporal changes occur in buffers C1 and S1. As noted in section 5.1.4 (see Figure 20), the magnitude of residential development over 10 years for both buffers are quite similar (C1=+15%, S1=+17%). In addition, the potential for future urbanization is quite high for both buffers (particularly C1) due to large decreases in agriculture (C1=-32%, S1=-22%) and notable increases in undeveloped land (C1=+34%, S1=+6%) which is prone to future development. Unfortunately, some of the best fish habitat in the basin is also found within these buffers. As discussed in section 5.2.1.1, the highest quality of proportional hydraulic habitat is found in reach C1 and the actual total amount is greatest in reach S1. The riffle:pool ratio is also higher in reaches C1 and S1 compared to their respective upper regions. These reaches are no doubt utilized extensively by salmonids for spawning and summer rearing purposes and are vulnerable to land use change impacts.

A cumulative analysis of streamside land use in Coghlan Creek and the Salmon River further emphasizes the trend towards urbanization within buffer segments C1 and S1. As examined in section 5.1.6, the intensity of residential and undeveloped areas in both streams (1989-90) increases dramatically from the upper reaches of C2 and S2 to the lower reaches of C1 and S1. If the intensity of land use change and their impacts on the aquatic environment within these buffer zones are severe enough, salmonids that normally migrate up through these areas to access important spawning and rearing areas may be reluctant or restricted from doing so.

In short, literature sources point out that intensive urban development can influence the quality and quantity of surface and sub-surface water and alter the channel morphology of a stream. These influences can in turn lead to a net loss of fish habitat thereby decreasing fish production. Both Coghlan Creek and the Salmon River contain excellent habitat which has historically produced a relatively large number of salmonid smolts (particularly in the Salmon River). Only recently has smolt production decreased in the Salmon River which could be related to substantial increases in streamside residential development over a 10 year period. The prospect for further residential development in both Coghlan Creek and the Salmon River is quite high, particularly in the lower reaches where the quality of fish habitat is also high. If the trend of urbanization continues near these streams, the possibility of declining fish populations due to habitat loss is a likely scenario.

CHAPTER 6

SYNTHESIS AND CONCLUSIONS

Interactions between the fisheries resource and human activities in the Fraser River Basin are vast and complex. As human populations and their associated activities continue to increase, particularly in the Lower Fraser Basin, it is expected that fish habitat alterations will become more widespread putting into question the sustainability of fish production. As a case study, this thesis examines the Salmon River basin and addresses land use and fish habitat as two components relevant to the sustainability of fish resources in the Lower Fraser Basin. The focus of this study was: 1) to quantify the distribution and recent temporal trends in land use using GIS techniques; 2) to identify and quantify prime fish habitat in the basin to provide a basis for assessing habitat deterioration in the future; 3) to characterize recent fish habitat changes; and 4) to describe trends and processes associated with fish habitat and streamside land use relationships.

The Salmon River watershed near Langley, British Columbia is one of the most productive and important spawning and rearing areas for coho salmon and cutthroat and steelhead trout in the Lower Fraser Basin. The watershed is dominantly rural but is under increasing pressure from rapid urbanization which is expected to put heavy strains on fish and fish habitat. To date, a flood gate and numerous culverts have created barriers to fish migration and impacted fish habitat. Problems associated with water withdrawals, the use of chemicals on agricultural land, stream bank breakdown by domestic stock, stream contaminants from residential development, and the removal of vegetation in streams and along riparian areas have all been documented in the basin. More dramatic changes related to water quality, water quantity and the stream channel morphology are likely to occur as intensive urbanization is carried out in the future. The combination of these processes is expected to deteriorate the habitat conditions in the watershed.

The following conclusions can be drawn from the study:

1. Land Use Dynamics (1979-80 to 1989-90)

The spatial distribution and temporal changes in land use were evaluated using GIS overlay techniques at a scale of 1:25,000 for the entire watershed area, a 500 meter buffer zone around the stream network, and 500 meter buffer segments around four key fish habitat reaches. The results show that agriculture is the dominant land use followed by undeveloped and residential land for both time periods in 1979-80 and 1989-90.

There are three trends that dominate the land use dynamics over the past 10 years for both the overall watershed and the stream network buffer: 1) agricultural land has decreased (9% and 10% respectively); 2) residential land has increased (3% and 2% respectively); and 3) undeveloped land has increased (4% and 6% respectively). Because undeveloped regions in this study include not only non-commercial forest but also idle land, the potential for future urban growth in these areas is quite high. A large portion of agricultural land went into an idle state while other large areas went directly into residential development. Compared to the overall watershed conditions, increases in undeveloped land are higher within the stream network buffer suggesting that the potential for urbanization is greater close to streams.

The largest land use change among the four fish habitat buffer segments was around the lower reach in Coghlan Creek with a 32% decrease in agriculture, a 15% increase in residential land, and a 34% increase in undeveloped areas. Relative to the other three buffer segments, the potential for urban development in this buffer is high. The buffer zone around the lower Salmon River reach had the largest actual increase in residential development at 17%. The stream reaches within these buffer zones contain some of the best juvenile summer rearing and spawning habitat in the entire basin.

A cumulative analysis of 1989-90 land use for the buffer zones in Coghlan Creek and the Salmon River showed that agricultural activities decreased in intensity while residential and undeveloped areas increased in intensity from the upstream buffers to the downstream buffers in both streams. Cumulative land use trends were more variable in the Salmon River than in Coghlan Creek.

The GIS techniques used in this study facilitated a quantitative evaluation of the land use dynamics at the watershed level and at smaller geographic areas within the watershed. This approach enables planners, engineers, policy makers and others, to examine land use dynamics from different perspectives moving from overall watershed conditions to more specific buffer segments along the stream. The spatial data that were generated can be easily stored in a format that allows for integration with other data bases. Finally, the entire land use digital data set is geographically referenced making it possible to add or update information so that more inter-relationships can be examined in the future.

The sources of error associated with the GIS digital data base for this project are difficult to quantify. Possible sources include: 1) error in the original national topographic base maps and original land use maps; 2) error added during data capture and storage (accuracy of hand digitizing and processing errors); 3) error associated with overlay procedures; and 4) error when data are extracted from the computer for display purposes. The accuracy of the scale itself should also be considered. A digitized line on the computer is about 0.5mm in width which represents 12.5 meters on the ground at 1:25,000 scale. The land use change figures should be viewed in the context of these errors and only overall trends rather than absolute values should be used as an information source.

2. Fish Habitat Inventory and Comparison

The 1990 fish habitat inventory was conducted in the best salmonid spawning and juvenile summer rearing reaches of Coghlan Creek and the Salmon River. All hydraulic units including riffles, glides, pools and sloughs were measured for length, wetted width, depth, and general substrate conditions. A significance test supported the notion that each type of hydraulic habitat differed from one another and that the units chosen for the classification were unique. In terms of preferred hydraulic habitat for salmonids, the results showed that proportionally, Coghlan Creek had more area and volume in riffles, glides and pools than the Salmon River. The actual total amount of preferred hydraulic habitat, however, was greater in the Salmon River. The total volume of the Salmon River study area was twice that of the Coghlan Creek site.

An attempt was made to compare habitat changes between an inventory done in 1980 and a randomly selected detailed survey of the 1990 inventory. Habitat components relating to stream morphology, substrate composition and salmonid cover requirements were to be compared for each hydraulic unit type between the two years. However, the 1980 survey data proved to be inadequate for a quantitative comparison because of experimental design problems.

3. Possible Linkages Between Land Use and Fish Habitat

There has been no evidence, up till now, to support the notion that urbanization in the Salmon River watershed is having a negative impact on fish and fish habitat. However, land use and fish habitat trends drawn from this study suggest that this scenario could be likely if fisheries perspectives are not incorporated into future land and water use decisions.

Literature sources have pointed out that urbanization usually has an adverse effect on the water quality, water quantity, and the stream morphology of a watershed which in turn can be detrimental to fish and fish habitat. Both reaches that were studied in Coghlan Creek and the Salmon River contain some of the best spawning and juvenile rearing habitat for salmonids in the basin, particularly in the lower reaches. The land within 250 meters of these lower reaches has recently been subject to substantial increases in residential development and the potential for more urbanization is high.

Culverts in the Salmon River watershed are examples of how trends toward urbanization are already creating problems associated with fish migration and changes in fish habitat. If more roads are constructed to service future residential developments, more culverts will likely be used at stream crossings.

The most interesting link was between preferred hydraulic habitat (on a volume basis) and the number of smolt catches as an indicator of salmonid productivity. From 1979 to 1989, the number of smolts migrating out of the Salmon River outnumbered those in Coghlan Creek by a factor of two to one. This ratio corresponds well with the volume of preferred hydraulic habitat and particularly with the total volume of water in each stream (8799 m^3 in the Salmon River study area versus 4186 m^3 in the Coghlan Creek study area). In 1990, however, the number of smolts trapped in the Salmon River were significantly lower than in Coghlan Creek. This distinct change could be an initial indication that increased urbanization close to highly productive habitat reaches in the Salmon River is influencing fish production in a negative way. Unfortunately, insufficient information is available to determine whether the decrease in Salmon River smolts is due to natural fluctuation of populations or related to changes in habitat.

CHAPTER 7

RECOMMENDATIONS

In view of this study, it is recommended that the effects of land use and land use change close to streams, particularly near critical fish habitat areas, be monitored to ensure a sustainable fisheries resource in this unique and highly productive basin. Also, alternatives to the use of culverts should be explored which do not alter the natural stream morphology and instream habitat conditions or prevent fish migration. Many of the existing culverts could be modified according to guidelines set out by the provincial Ministry of Environment and the federal Department of Fisheries and Oceans in order to meet these criteria. (see Dane, 1983; Fisheries and Oceans Canada, 1983; Chilibeck et al., 1992).

It is also recommended that salmonids and other fish stocks and their habitat be continually monitored in Coghlan Creek and the Salmon River to document linkages between urbanization, changes in fish habitat and fish production.

Because an extensive amount of information was collected throughout this project from literature reviews, personal interviews and field observations, the following list of additional recommendations are noted:

a) The Salmon River flood gate at the Fraser River confluence must be replaced with a new pump system that is conducive to fish migration. This most obvious and critical point source of fish mortality must be dealt with immediately if sustainable development in the basin includes a productive fisheries resource. Also, the fishway at 64th avenue is poorly designed and needs to be replaced to enable proper upstream migration of fish.

b) Water licenses should be monitored to account for actual withdrawals in order to protect fish from low flow conditions during the summer months. Also, the provincial Water Act must establish more comprehensive minimum flow and water quality standards, and include fish as a formally recognized user of water!

c) Better land use planning in the interest of fish and fish habitat should be incorporated in the Municipal Planning Act with the input of provincial and federal fisheries staff. This would help change the present reactive approach taken through the referral process triggered by individual property development proposals.

d) Although there has been a large increase in fencing around riparian areas over the last 10 years, more fencing is required adjacent to fields that support livestock in the upper regions of the watershed. This will help to minimize stream bank degradation and reduce sediment in streams.

e) The Salish sucker is a rare and unique fish which has been documented in small tributaries in the upper regions of the watershed. These fish require clean, small sized gravel substrate for spawning purposes. In order to keep populations from further decline, this critical habitat should be preserved. More research on the distribution and the habitat requirements of the Salish sucker is presently being conducted by the provincial Fisheries Branch.

f) The Ministry of Environment Lands and Parks (Fisheries Branch) is currently using historic fish distribution and habitat data from studies by DeLeeuw (1981, 1982) and DeLeeuw and Stuart (1981) to help develop sea-run cutthroat production models for the Lower Mainland and Sechelt Peninsula. Because these studies were based on poor experimental design techniques, any production models assembled should be viewed with scepticism.

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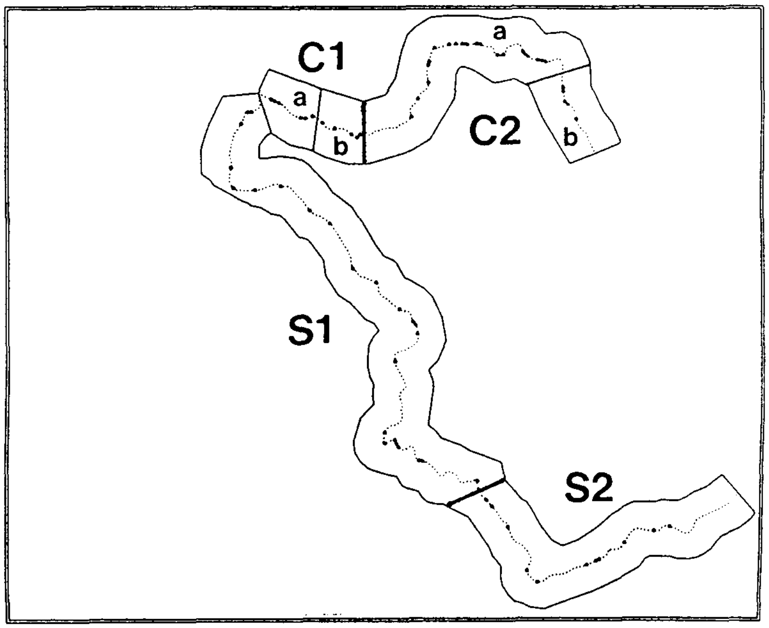
Appendix A

Comparison of Average Discharge (Q) Between 1980 and 1990 and Percent Gradient for Reaches C1 (a) and (b), C2 (a) and (b), S1, and S2.

NOTE: Only riffles and glides and used to calculate average discharge.

Figure showing location of stream reaches



		Q 1980	Q 1990	% GRADIENT
C1 (a)	Average =	0.14	0.22	0-0.5
C1 (b)	Average =	0.30	0.26	1.0-3.0
C2 (a)	Average =	0.01	0.08	0.5-1.0
C2 (b)	Average =	0.03	0.05	1.0-3.0
S1	Average =	0.32	0.16	1.0-3.0
S2	Average =	0.09	0.06	0.5-1.0

Appendix B

General Habitat Survey (1990) Data Collected in Coghlan Creek (C) and the Salmon River (S)

Unit 1 = Riffles, Unit 2 = Glides, Unit 3 = Pools, Unit 4 = Sloughs

Length, Wetted Width and Depth - measured in meters (m)

Area measured in square meters (m^2)

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C1.1	1	1	8.50	1.50	12.75	0.10	20	60	20
C1.2	2	2	13.00	1.50	19.50	0.23	20	60	20
C1.3	3	1	13.50	3.00	40.50	0.15	20	50	30
C1.4	4	2	16.00	2.50	40.00	0.32	50	40	10
C1.5	5	1	18.00	3.00	54.00	0.24	30	60	10
C1.6	6	2	7.50	2.50	18.75	0.30	50	40	10
C1.7	7	1	6.50	4.50	29.25	0.12	40	50	10
C1.8	8	2	9.00	3.00	27.00	0.23	60	20	20
C2.1	9	3	3.00	5.00	15.00	0.60	30	60	10
C2.2	10	2	12.00	4.00	48.00	0.25	40	50	10
C2.3	11	1	6.50	2.50	16.25	0.15	10	60	30
C2.4	12	2	5.00	2.50	12.50	0.28	10	70	20
C2.5	13	1	4.00	4.00	16.00	0.20	10	70	20
C2.6	14	3	4.00	2.00	8.00	0.50	20	50	30
C2.7	15	2	37.00	4.00	148.00	0.30	20	50	30
C2.8	16	3	3.00	3.00	9.00	0.34	40	30	30
C2.9	17	1	12.50	2.00	25.00	0.05	10	70	20
C2.10	18	3	10.00	8.00	80.00	0.56	30	60	10
C2.11	19	2	7.00	2.50	17.50	0.24	20	60	20
C2.12	20	1	15.00	3.00	45.00	0.15	20	70	10
C2.13	21	2	7.00	3.00	21.00	0.34	30	60	10
C2.14	22	3	5.50	4.00	22.00	0.46	50	40	10
C2.15	23	2	8.50	2.50	21.25	0.33	30	50	20
C2.16	24	1	4.00	3.50	14.00	0.09	20	60	20
C2.17	25	2	22.50	4.50	101.25	0.24	40	50	10
C2.18	26	1	8.50	4.00	34.00	0.07	10	80	10
C2.19	27	4	20.00	4.50	90.00	0.43	60	30	10
C2.20	28	2	24.00	2.50	60.00	0.13	20	70	10
C3.1	29	1	5.50	2.00	11.00	0.10	10	80	10
C3.2	30	2	20.00	3.00	60.00	0.21	30	50	20
C3.3	31	1	4.00	6.00	24.00	0.11	10	70	20
C3.4	32	4	15.00	6.00	90.00	0.34	70	20	10
C3.5	33	2	6.00	3.00	18.00	0.22	30	60	10
C3.6	34	1	6.50	2.50	16.25	0.07	20	70	10
C3.7	35	2	11.00	3.50	38.50	0.20	70	20	10
C3.8	36	3	15.00	20.00	300.00	0.45	30	60	10
C3.9	37	4	45.00	5.00	225.00	0.44	20	60	20
C3.10	38	2	10.00	3.00	30.00	0.32	10	60	30
C3.11	39	1	6.00	5.00	30.00	0.12	10	70	20
C3.12	40	2	20.00	4.00	80.00	0.23	30	60	10
C3.13	41	4	20.00	1.00	20.00	0.40	50	40	10
C3.14	42	2	16.00	2.50	40.00	0.28	20	60	20
C3.15	43	1	7.00	2.00	14.00	0.12	10	70	20
C3.16	44	2	17.00	4.50	76.50	0.12	30	60	10
C3.17	45	1	2.00	2.50	5.00	0.20	10	70	20
C3.18	46	2	7.00	4.50	31.50	0.26	30	60	10
C3.19	47	1	3.50	3.50	12.25	0.10	10	60	30
C3.20	48	4	23.00	3.50	80.50	0.34	30	50	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C3.21	49	2	10.00	2.50	25.00	0.25	20	50	30
C3.22	50	1	6.00	3.00	18.00	0.15	10	60	30
C3.23	51	2	11.50	3.00	34.50	0.20	20	60	20
C3.24	52	1	3.50	3.50	12.25	0.29	10	70	20
C3.25	53	3	5.50	4.00	22.00	0.41	70	20	10
C4.1	54	1	2.00	2.50	5.00	0.10	10	60	30
C4.2	55	2	3.50	1.50	5.25	0.20	30	50	20
C4.3	56	1	12.00	2.00	24.00	0.16	10	50	40
C4.4	57	2	10.00	4.00	40.00	0.26	30	60	10
C4.5	58	1	20.00	1.00	20.00	0.13	10	60	30
C4.6	59	2	15.00	5.00	75.00	0.35	60	30	10
C4.7	60	4	17.00	2.50	42.50	0.32	30	60	10
C4.8	61	2	9.00	2.00	18.00	0.22	30	60	10
C4.9	62	1	7.00	2.50	17.50	0.12	10	70	20
C4.10	63	3	7.00	5.00	35.00	0.49	70	30	10
C4.11	64	2	12.00	2.50	30.00	0.19	30	60	10
C4.12	65	3	15.00	3.00	45.00	0.36	70	20	10
C4.13	66	2	10.00	1.50	15.00	0.16	20	70	10
C4.14	67	3	3.00	3.00	9.00	0.30	40	50	10
C4.15	68	2	21.00	2.50	52.50	0.20	20	70	10
C4.16	69	1	13.00	5.00	65.00	0.10	20	70	10
C4.17	70	2	11.00	3.00	33.00	0.25	20	60	20
C4.18	71	1	3.00	2.50	7.50	0.13	20	70	10
C4.19	72	2	9.50	3.00	28.50	0.23	30	50	20
C4.20	73	1	6.00	2.00	12.00	0.06	10	70	20
C4.21	74	2	7.50	3.00	22.50	0.16	30	60	10
C4.22	75	1	15.00	3.00	45.00	0.06	40	50	10
C4.23	76	2	12.00	5.00	60.00	0.20	20	70	10
C4.24	77	1	6.50	2.50	16.25	0.11	10	80	10
C4.25	78	2	6.00	2.00	12.00	0.30	20	70	10
C4.26	79	3	5.00	9.50	47.50	0.62	40	40	20
C4.27	80	1	4.50	1.50	6.75	0.12	10	70	20
C4.28	81	3	7.50	3.50	26.25	0.34	40	50	10
C4.29	82	2	10.00	3.00	30.00	0.29	20	60	20
C4.30	83	1	6.00	4.50	27.00	0.09	20	60	20
C4.31	84	2	22.00	5.00	110.00	0.19	20	60	20
C4.32	85	1	17.00	5.00	85.00	0.07	10	60	30
C4.33	86	2	8.00	3.50	28.00	0.23	10	60	30
C4.34	87	1	9.00	5.00	45.00	0.10	10	50	40
C4.35	88	2	42.00	3.00	126.00	0.23	10	50	40
C4.36	89	1	14.50	3.50	50.75	0.20	10	40	50
C4.37	90	3	10.00	6.00	60.00	0.67	20	50	30
C4.38	91	1	12.00	3.00	36.00	0.13	10	70	20
C4.39	92	3	10.00	6.50	65.00	0.67	30	50	20
C4.40	93	2	6.00	3.00	18.00	0.17	20	60	20
C4.41	94	1	25.00	4.00	100.00	0.06	20	70	10
C4.42	95	2	31.00	3.00	93.00	0.23	20	70	10
C4.43	96	1	8.00	2.50	20.00	0.13	20	70	10
C4.44	97	2	20.00	3.00	60.00	0.12	30	60	10
C4.45	98	1	6.00	1.50	9.00	0.06	10	80	10
C4.46	99	3	15.00	5.00	75.00	0.46	40	20	40
C4.47	100	1	13.50	5.00	67.50	0.09	10	60	30
C4.48	101	2	35.00	4.00	140.00	0.27	20	60	20
C4.49	102	1	14.00	5.00	70.00	0.12	10	40	50
C4.50	103	2	9.00	4.00	36.00	0.25	30	50	20
C4.51	104	1	7.00	3.50	24.50	0.15	20	60	20
C4.52	105	4	7.00	6.00	42.00	0.42	40	20	40
C4.53	106	1	7.50	4.50	33.75	0.10	10	60	30
C4.54	107	2	10.00	4.00	40.00	0.23	20	50	30
C4.55	108	1	30.00	4.50	135.00	0.11	20	30	50
C4.56	109	2	9.00	4.50	40.50	0.31	30	50	20
C4.57	110	1	9.50	3.00	28.50	0.13	20	40	40
C4.58	111	2	6.00	3.50	21.00	0.22	20	60	20
C4.59	112	1	12.00	2.50	30.00	0.12	10	60	30
C4.60	113	2	3.00	3.00	9.00	0.24	30	50	20
C4.61	114	1	18.00	2.00	36.00	0.14	20	60	20
C4.62	115	2	15.00	3.50	52.50	0.24	10	60	30

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C4.63	116	4	6.00	4.50	27.00	0.37	40	40	20
C4.64	117	2	4.00	4.00	16.00	0.19	50	50	0
C4.65	118	1	18.00	3.00	54.00	0.14	20	70	10
C4.66	119	2	10.00	3.50	35.00	0.27	20	70	10
C4.67	120	1	4.00	2.00	8.00	0.16	20	70	10
C4.68	121	2	20.00	5.50	110.00	0.16	30	50	20
C4.69	122	3	7.00	4.50	31.50	0.45	30	40	30
C4.70	123	1	36.00	5.00	180.00	0.14	20	50	30
C4.71	124	2	10.00	5.00	50.00	0.31	40	40	20
C4.72	125	1	22.00	4.00	88.00	0.15	20	60	20
C4.73	126	4	10.00	3.50	35.00	0.26	30	50	20
C4.74	127	3	4.00	5.00	20.00	0.53	50	30	20
C4.75	128	4	15.00	5.00	75.00	0.38	20	50	30
C4.76	129	1	20.00	4.00	80.00	0.15	20	60	20
C4.77	130	2	8.00	3.50	28.00	0.32	30	60	10
C4.78	131	3	7.00	4.00	28.00	0.47	70	20	10
C4.79	132	1	16.00	3.50	56.00	0.14	20	50	30
C4.80	133	2	4.00	2.00	8.00	0.23	20	60	20
C4.81	134	1	11.50	3.00	34.50	0.11	20	60	20
C4.82	135	2	28.00	4.00	112.00	0.22	20	60	20
C5.1	136	1	21.00	2.00	42.00	0.18	10	70	20
C5.2	137	3	9.00	4.00	36.00	0.50	70	20	10
C5.3	138	2	10.00	3.00	30.00	0.18	20	60	20
C5.4	139	3	19.00	4.00	76.00	0.65	20	60	20
C5.5	140	1	10.00	4.00	40.00	0.10	10	70	20
C5.6	141	4	11.00	5.00	55.00	0.60	30	60	10
C5.7	142	2	15.00	4.00	60.00	0.20	30	60	10
C5.8	143	1	17.00	4.00	68.00	0.28	10	70	20
C5.9	144	2	26.00	4.00	104.00	0.18	20	70	10
C5.10	145	3	14.00	4.50	63.00	1.10	40	50	10
C5.11	146	1	28.00	3.00	84.00	0.10	10	60	30
C5.12	147	2	14.00	3.00	42.00	0.20	10	70	20
C5.13	148	1	11.00	4.00	44.00	0.10	10	70	20
C5.14	149	2	18.00	4.00	72.00	0.50	20	70	10
C5.15	150	3	15.00	4.00	60.00	0.50	30	50	20
C5.16	151	1	7.00	3.50	24.50	0.10	10	70	20
C5.17	152	2	26.00	3.50	91.00	0.30	20	60	20
C5.18	153	1	11.00	2.00	22.00	0.15	20	70	10
C5.19	154	3	5.50	5.00	27.50	0.40	50	40	10
C5.20	155	2	36.00	3.00	108.00	0.20	30	50	20
C5.21	156	1	32.00	3.00	96.00	0.10	30	50	20
C5.22	157	3	12.00	4.00	48.00	0.50	40	50	10
C5.23	158	1	6.00	2.00	12.00	0.10	10	80	10
C5.24	159	2	5.00	2.00	10.00	0.25	30	60	10
C5.25	160	1	8.00	2.00	16.00	0.15	20	70	10
C5.26	161	3	6.00	5.00	30.00	0.60	50	40	10
C5.27	162	1	6.00	1.00	6.00	0.10	20	60	20
C5.28	163	2	18.00	3.00	54.00	0.15	20	60	20
C5.29	164	1	5.00	2.00	10.00	0.15	20	70	10
C5.30	165	3	11.00	4.00	44.00	0.50	50	40	10
C5.31	166	1	14.00	2.00	28.00	0.10	10	70	20
C5.32	167	2	46.00	3.50	161.00	0.15	30	60	10
C5.33	168	3	5.00	5.00	25.00	0.35	50	40	10
C5.34	169	2	29.00	3.00	87.00	0.20	10	70	20
C5.35	170	1	30.00	2.00	60.00	0.10	10	70	20
C6.1	171	3	6.00	5.00	30.00	0.50	50	40	10
C6.2	172	1	24.00	2.00	48.00	0.10	10	70	20
C6.3	173	3	8.00	3.50	28.00	0.40	30	60	10
C6.4	174	2	23.00	3.50	80.50	0.25	10	70	20
C6.5	175	1	5.00	1.50	7.50	0.15	10	60	30
C6.6	176	2	36.00	2.00	72.00	0.30	10	70	20
C6.7	177	1	10.00	1.00	10.00	0.10	10	60	30
C6.8	178	3	8.00	3.00	24.00	0.35	20	70	10
C6.9	179	1	6.00	2.00	12.00	0.10	10	80	10
C6.10	180	2	12.00	1.50	18.00	0.20	20	70	10
C6.11	181	3	5.00	4.00	20.00	0.45	40	50	10
C6.12	182	1	7.00	2.00	14.00	0.15	10	70	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C6.13	183	4	24.00	3.00	72.00	0.45	30	60	10
C6.14	184	2	14.00	2.00	28.00	0.20	10	70	20
C6.15	185	3	7.00	4.00	28.00	0.70	20	50	30
C6.16	186	1	5.00	2.00	10.00	0.10	10	70	20
C6.17	187	3	9.00	4.50	40.50	0.60	20	50	30
C6.18	188	2	5.00	2.50	12.50	0.40	10	70	20
C6.19	189	1	5.00	2.00	10.00	0.10	10	70	20
C6.20	190	2	12.00	2.00	24.00	0.20	20	70	10
C6.21	191	1	4.00	1.00	4.00	0.10	10	70	20
C6.22	192	2	10.00	3.00	30.00	0.30	10	70	20
C6.23	193	1	6.00	2.00	12.00	0.10	10	70	20
C6.24	194	2	15.00	3.00	45.00	0.20	20	60	20
C6.25	195	1	8.00	4.00	32.00	0.10	10	70	20
C6.26	196	2	10.00	4.00	40.00	0.30	10	70	20
C6.27	197	1	5.00	3.00	15.00	0.10	10	70	20
C6.28	198	2	21.00	3.50	73.50	0.25	10	60	30
C6.29	199	1	4.00	4.00	16.00	0.10	20	70	10
C6.30	200	2	18.00	3.00	54.00	0.40	30	60	10
C6.31	201	1	3.00	2.00	6.00	0.10	30	50	20
C6.32	202	2	16.00	3.00	48.00	0.20	30	50	20
C6.33	203	1	10.00	3.00	30.00	0.10	30	50	20
C6.34	204	2	18.00	4.00	72.00	0.45	40	30	30
C6.35	205	1	18.00	4.00	72.00	0.10	30	50	20
C6.36	206	2	15.00	3.00	45.00	0.20	30	40	30
C6.37	207	1	7.00	1.00	7.00	0.10	20	50	30
C7.1	208	2	25.00	2.00	50.00	0.15	30	60	10
C7.2	209	4	13.00	1.00	13.00	0.25	20	80	0
C7.3	210	3	7.50	5.00	37.50	0.75	60	40	0
C7.4	211	2	28.00	2.50	70.00	0.30	50	50	0
C7.5	212	1	11.00	3.00	33.00	0.10	20	80	0
C7.6	213	2	32.00	2.00	64.00	0.15	20	80	0
C7.7	214	1	9.00	1.50	13.50	0.10	20	80	0
C7.8	215	4	50.00	2.00	100.00	0.25	30	70	0
C7.9	216	1	5.00	1.00	5.00	0.15	20	80	0
C7.10	217	3	10.00	3.00	30.00	0.50	50	50	0
C7.11	218	1	9.00	1.00	9.00	0.10	30	60	10
C7.12	219	2	12.00	3.00	36.00	0.60	30	60	10
C7.13	220	1	10.00	2.00	20.00	0.10	30	60	10
C7.14	221	2	15.00	3.00	45.00	0.35	30	70	0
C7.15	222	1	4.00	1.00	4.00	0.10	30	70	0
C7.16	223	3	9.00	4.00	36.00	0.30	40	60	0
C7.17	224	1	7.00	1.00	7.00	0.10	30	70	0
C7.18	225	4	17.00	3.00	51.00	0.35	30	70	0
C7.19	226	2	12.00	2.00	24.00	0.25	40	60	0
C7.20	227	1	5.00	1.00	5.00	0.10	20	70	10
C7.21	228	2	6.00	1.00	6.00	0.25	20	70	10
C7.22	229	3	7.00	4.00	28.00	0.80	40	40	20
C7.23	230	4	8.00	2.00	16.00	0.50	30	60	10
C7.24	231	2	6.00	2.00	12.00	0.30	20	70	10
C7.25	232	3	6.00	3.00	18.00	0.40	40	40	20
C7.26	233	1	4.00	1.00	4.00	0.10	20	70	10
C7.27	234	2	18.00	1.00	18.00	0.30	30	70	0
C7.28	235	1	7.00	1.00	7.00	0.10	10	70	20
C7.29	236	2	12.00	2.00	24.00	0.40	30	60	10
C7.30	237	1	8.00	1.00	8.00	0.10	10	80	10
C7.31	238	4	12.00	1.00	12.00	0.35	30	60	10
C7.32	239	3	7.00	3.00	21.00	0.50	60	30	10
C7.33	240	1	4.00	3.00	12.00	0.10	10	80	10
C7.34	241	4	15.00	2.00	30.00	0.40	30	60	10
C7.35	242	1	5.00	2.00	10.00	0.10	30	60	10
C7.36	243	2	10.00	3.00	30.00	0.20	20	70	10
C7.37	244	1	3.00	1.00	3.00	0.10	10	70	20
C7.38	245	2	7.00	2.00	14.00	0.20	20	70	10
C7.39	246	1	7.00	3.00	21.00	0.10	10	80	10
C7.40	247	2	8.00	2.00	16.00	0.25	20	70	10
C7.41	248	1	6.00	2.00	12.00	0.10	10	70	20
C7.42	249	2	28.00	3.50	98.00	0.30	30	60	10

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C7.43	250	1	3.00	1.00	3.00	0.10	20	70	10
C7.44	251	2	7.00	2.00	14.00	0.40	20	70	10
C7.45	252	4	14.00	2.00	28.00	0.30	40	50	10
C7.46	253	2	6.00	2.00	12.00	0.20	20	60	20
C7.47	254	1	5.00	1.00	5.00	0.10	10	80	10
C7.48	255	2	9.00	2.50	22.50	0.60	30	60	10
C7.49	256	1	3.00	1.00	3.00	0.10	10	80	10
C7.50	257	2	12.00	1.00	12.00	0.15	20	70	10
C7.51	258	1	2.00	2.00	4.00	0.10	10	70	20
C7.52	259	4	7.00	1.00	7.00	0.35	30	60	10
C7.53	260	1	5.00	1.00	5.00	0.10	10	80	10
C7.54	261	2	9.00	1.00	9.00	0.10	20	70	10
C7.55	262	4	11.00	2.00	22.00	0.40	30	60	10
C7.56	263	1	9.00	1.00	9.00	0.15	20	70	10
C7.57	264	2	24.00	3.00	72.00	0.20	20	60	20
C7.58	265	1	6.00	1.00	6.00	0.10	10	80	10
C7.59	266	2	9.00	2.00	18.00	0.15	10	80	10
C7.60	267	1	5.00	1.00	5.00	0.10	10	80	10
C7.61	268	2	4.00	3.00	12.00	0.15	10	70	20
C7.62	269	1	4.00	2.00	8.00	0.10	10	80	10
C7.63	270	3	8.00	2.50	20.00	0.75	30	60	10
C7.64	271	2	16.00	2.00	32.00	0.50	20	60	20
C7.65	272	1	3.00	2.00	6.00	0.10	10	80	10
C7.66	273	2	13.00	1.00	13.00	0.15	20	70	10
C7.67	274	1	8.00	1.00	8.00	0.10	10	80	10
C7.68	275	2	8.00	2.00	16.00	0.20	10	80	10
C7.69	276	1	7.00	1.00	7.00	0.10	10	70	20
C7.70	277	2	11.00	1.00	11.00	0.10	20	70	10
C7.71	278	1	8.00	1.00	8.00	0.10	10	80	10
C7.72	279	2	8.00	3.00	24.00	0.20	20	70	10
C7.73	280	1	3.00	2.00	6.00	0.10	10	80	10
C7.74	281	4	12.00	3.00	36.00	0.75	30	60	10
C7.75	282	2	9.00	2.00	18.00	0.40	20	70	10
C7.76	283	1	3.00	1.00	3.00	0.10	20	70	10
C7.77	284	2	5.00	2.00	10.00	0.20	40	50	10
C7.78	285	1	12.00	1.00	12.00	0.10	20	70	10
C7.79	286	4	11.00	1.50	16.50	0.25	20	70	10
C7.80	287	2	5.00	1.00	5.00	0.15	20	70	10
C7.81	288	1	5.00	1.00	5.00	0.10	10	80	10
C7.82	289	4	12.00	2.00	24.00	0.20	30	60	10
C7.83	290	3	9.00	5.00	45.00	0.30	30	50	20
C7.84	291	1	7.00	1.00	7.00	0.10	10	70	20
C7.85	292	2	19.00	2.50	47.50	0.20	20	60	20
C7.86	293	1	9.00	1.00	9.00	0.10	10	70	20
C7.87	294	3	8.00	3.00	24.00	0.80	30	50	20
C7.88	295	1	25.00	3.00	75.00	0.10	10	70	20
C7.89	296	2	24.00	3.00	72.00	0.50	10	70	20
C7.90	297	1	3.00	1.00	3.00	0.10	10	70	20
C7.91	298	2	24.00	2.00	48.00	0.20	10	70	20
C7.92	299	1	3.00	1.00	3.00	0.10	20	70	10
C7.93	300	4	8.00	2.00	16.00	0.30	30	60	10
C7.94	301	2	17.00	2.50	42.50	0.20	20	70	10
C7.95	302	1	4.00	3.00	12.00	0.10	10	70	20
C7.96	303	4	11.00	3.00	33.00	0.30	30	50	20
C7.97	304	2	14.00	3.00	42.00	0.20	10	70	20
C7.98	305	1	4.00	2.00	8.00	0.10	10	70	20
C7.99	306	2	33.00	2.50	82.50	0.25	20	60	20
C7.100	307	1	22.00	2.50	55.00	0.10	10	60	30
C7.101	308	2	12.00	3.00	36.00	0.40	20	50	30
C7.102	309	1	2.00	2.00	4.00	0.10	10	60	30
C7.103	310	2	22.00	3.00	66.00	0.35	10	60	30
C7.104	311	1	4.00	2.00	8.00	0.10	10	50	40
C7.105	312	3	8.00	3.00	24.00	0.40	30	40	30
C7.106	313	2	8.00	3.00	24.00	0.20	10	40	50
C7.107	314	1	8.00	1.00	8.00	0.10	20	10	70
C7.108	315	3	18.00	4.00	72.00	0.40	20	20	60
C8.1	316	2	15.00	2.50	37.50	0.25	20	60	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C8.2	317	3	8.00	7.00	56.00	0.75	20	50	30
C8.3	318	2	38.00	3.50	133.00	0.25	20	70	20
C8.4	319	1	8.00	1.50	12.00	0.10	10	80	10
C8.5	320	3	10.00	4.50	45.00	0.60	30	50	20
C8.6	321	2	18.00	3.50	63.00	0.25	20	70	10
C8.7	322	1	6.50	1.50	9.75	0.10	10	80	10
C8.8	323	4	12.00	3.50	42.00	0.35	30	60	10
C8.9	324	2	8.00	2.00	16.00	0.25	10	70	20
C8.10	325	1	15.00	1.50	22.50	0.10	10	70	20
C8.11	326	2	10.00	1.50	15.00	0.20	20	60	20
C8.12	327	1	4.00	3.00	12.00	0.10	20	70	10
C8.13	328	2	13.00	3.50	45.50	0.30	20	70	10
C8.14	329	1	3.00	2.00	6.00	0.10	10	70	20
C8.15	330	2	16.00	3.00	48.00	0.20	20	60	20
C8.16	331	1	7.00	1.00	7.00	0.10	10	60	20
C8.17	332	4	16.00	4.00	64.00	0.25	20	60	20
C8.18	333	3	5.00	3.50	17.50	0.60	30	50	20
C8.19	334	1	5.00	4.00	20.00	0.10	10	60	30
C8.20	335	4	12.00	4.50	54.00	0.30	20	60	20
C8.21	336	2	21.00	2.00	42.00	0.20	20	60	20
C8.22	337	3	5.00	3.00	15.00	0.50	30	60	10
C8.23	338	1	19.00	2.00	38.00	0.10	10	70	20
C8.24	339	2	13.00	1.50	19.50	0.15	10	70	20
C8.25	340	1	8.00	4.50	36.00	0.10	10	60	30
C8.26	341	2	21.00	1.50	31.50	0.15	20	70	10
C8.27	342	1	6.00	3.50	21.00	0.10	10	70	20
C8.28	343	2	12.00	2.00	24.00	0.15	20	60	20
C8.29	344	1	20.00	1.50	30.00	0.10	40	30	30
C8.30	345	3	4.00	4.00	16.00	0.50	30	50	20
C8.31	346	1	10.00	1.00	10.00	0.10	10	70	20
C8.32	347	2	20.00	2.00	40.00	0.15	10	70	20
C8.33	348	1	17.00	1.00	17.00	0.10	10	70	20
C8.34	349	3	4.00	4.00	16.00	0.50	20	70	10
C8.35	350	2	7.00	2.00	14.00	0.20	20	60	20
C8.36	351	1	3.00	1.50	4.50	0.10	10	70	20
C8.37	352	2	17.00	2.00	34.00	0.25	20	60	20
C8.38	353	1	6.00	1.00	6.00	0.10	30	60	10
C8.39	354	4	10.00	3.00	30.00	0.30	20	60	20
C8.40	355	1	22.00	3.00	66.00	0.10	10	70	20
C8.41	356	2	17.00	2.00	34.00	0.25	20	60	20
C8.42	357	4	10.00	3.00	30.00	0.25	20	70	10
C8.43	358	1	12.00	2.50	30.00	0.10	10	70	20
C8.44	359	2	32.00	2.00	64.00	0.15	10	70	20
C8.45	360	1	4.00	1.00	4.00	0.10	10	70	20
C8.46	361	2	13.00	1.00	13.00	0.10	20	70	10
C8.47	362	4	12.00	4.00	48.00	0.30	30	60	10
C8.48	363	1	9.00	1.00	9.00	0.10	10	70	20
C8.49	364	2	7.00	3.00	21.00	0.20	20	50	30
C8.50	365	1	9.00	2.00	18.00	0.10	10	60	30
C8.51	366	4	12.00	3.00	36.00	0.25	10	70	20
C8.52	367	1	15.00	1.50	22.50	0.10	10	70	20
C8.53	368	3	10.00	4.00	40.00	0.70	40	50	10
C8.54	368	2	28.00	1.50	42.00	0.20	20	70	10
C8.55	370	3	8.00	5.00	40.00	0.50	40	50	10
C8.56	371	2	8.00	1.50	12.00	0.20	20	50	30
C8.57	372	1	10.00	1.50	15.00	0.10	10	60	30
C8.58	373	4	15.00	2.00	30.00	0.15	20	70	10
C8.59	374	1	6.00	1.00	6.00	0.10	10	70	20
C8.60	375	2	12.00	1.50	18.00	0.15	10	70	20
C8.61	376	1	5.00	2.50	12.50	0.10	10	70	20
C8.62	377	2	20.00	2.00	40.00	0.15	10	70	20
C8.63	378	1	8.00	1.00	8.00	0.15	30	60	10
C8.64	379	3	4.00	4.00	16.00	0.50	30	60	10
C8.65	380	2	15.00	1.50	22.50	0.15	20	60	20
C8.66	381	1	7.00	1.50	10.50	0.10	10	60	30
C8.67	382	3	4.50	4.00	18.00	0.90	40	40	20
C8.68	383	1	2.00	1.00	2.00	0.10	10	80	10

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
C8.69	384	4	5.00	4.00	20.00	0.30	30	60	10
C8.70	385	2	15.00	2.00	30.00	0.15	20	60	20
C8.71	386	4	12.00	5.00	60.00	0.20	20	70	10
C8.72	387	2	10.00	1.00	10.00	0.15	40	50	10
C8.73	388	4	30.00	2.50	75.00	0.20	30	60	10
C8.74	389	1	10.00	0.50	5.00	0.10	10	80	10
C8.75	390	2	18.00	1.00	18.00	0.20	20	70	10
C8.76	391	1	7.00	1.50	10.50	0.10	10	70	20
C8.77	392	2	8.00	1.50	12.00	0.20	10	70	20
C8.78	393	1	8.00	1.00	8.00	0.10	10	60	30
C8.79	394	3	7.00	2.50	17.50	0.50	30	60	10
C8.80	395	1	7.00	2.00	14.00	0.10	10	70	20
C8.81	396	2	18.00	2.00	36.00	0.15	10	80	10
C8.82	397	4	15.00	3.50	52.50	0.30	30	60	10
C8.83	398	1	12.00	1.50	18.00	0.10	10	70	20
C8.84	399	2	29.00	2.50	72.50	0.20	20	70	10
C8.85	400	1	8.00	3.00	24.00	0.10	10	70	20
C8.86	401	2	9.00	3.00	27.00	0.25	30	60	10
C8.87	402	1	5.00	2.00	10.00	0.10	10	70	20
C8.88	403	4	10.00	4.50	45.00	0.20	20	60	20
C8.89	404	1	32.00	1.50	48.00	0.10	10	70	20
C8.90	405	2	9.00	1.50	13.50	0.15	10	70	20
C8.91	406	1	40.00	2.50	100.00	0.10	10	60	30
C8.92	407	4	15.00	3.00	45.00	0.35	20	70	10
C8.93	408	2	25.00	1.50	37.50	0.20	20	60	20
C8.94	409	1	8.00	3.00	24.00	0.10	20	60	20
C8.95	410	3	5.00	5.00	25.00	0.40	30	50	20
C8.96	411	1	1.00	1.00	1.00	0.10	10	10	80
C8.97	412	3	3.00	3.00	9.00	0.35	40	30	30
C8.98	413	1	8.00	2.50	20.00	0.10	10	60	30
C8.99	414	2	30.00	2.50	75.00	0.20	20	60	20
C8.100	415	1	8.00	1.50	12.00	0.10	10	70	20
C8.101	416	4	20.00	5.00	100.00	0.35	30	60	10
C8.102	417	2	16.00	2.00	32.00	0.20	20	60	20
C8.103	418	1	28.00	3.00	84.00	0.10	10	70	20
C8.104	419	2	24.00	2.00	48.00	0.15	10	60	30
C8.105	420	1	13.00	2.00	26.00	0.10	10	60	30
C8.106	421	4	13.00	3.50	45.50	0.20	10	60	30
C8.107	422	1	10.00	1.00	10.00	0.10	10	60	30
C8.108	423	3	6.00	6.00	36.00	0.40	20	50	30
C8.109	424	2	30.00	2.00	60.00	0.15	10	70	20
C8.110	425	1	25.00	3.00	75.00	0.20	20	60	20
C8.111	426	2	22.00	2.00	44.00	0.15	10	70	20
C8.112	427	1	14.00	2.00	28.00	0.10	10	60	30
C8.113	428	2	34.00	1.50	51.00	0.15	20	60	20
C8.114	429	1	10.00	1.00	10.00	0.10	10	60	30
C8.115	430	2	10.00	2.00	20.00	0.15	10	50	40
C8.116	431	1	27.00	1.00	27.00	0.10	10	50	40
C8.117	432	3	12.00	8.00	96.00	2.00	30	45	25
C9.1	433	1	5.00	1.00	5.00	0.10	20	60	20
C9.2	434	2	6.00	2.50	15.00	0.15	30	50	20
C9.3	435	4	5.00	3.50	17.50	0.20	30	50	20
C9.4	436	1	4.00	0.50	2.00	0.10	10	80	10
C9.5	437	4	35.00	3.00	105.00	0.20	20	60	20
C9.6	438	1	12.00	3.00	36.00	0.10	20	70	10
S1.1	1	2	16.00	3.00	48.00	0.20	20	50	30
S1.2	2	1	30.00	4.50	135.00	0.10	20	60	20
S1.3	3	4	220.00	6.00	1320.0	0.50	30	50	20
S1.4	4	1	10.00	4.00	40.00	0.10	10	50	40
S1.5	5	2	12.00	4.50	54.00	0.15	10	60	30
S1.6	6	1	14.00	4.50	63.00	0.10	10	60	30
S1.7	7	2	18.00	3.00	54.00	0.40	30	50	20
S1.8	8	1	4.00	3.00	12.00	0.10	10	70	20
S1.9	9	3	11.00	6.00	66.00	1.00	30	50	20
S1.10	10	2	16.00	3.00	48.00	0.20	20	60	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S1.11	11	3	4.00	4.00	16.00	0.90	30	50	20
S1.12	12	1	6.00	3.50	21.00	0.10	10	70	20
S1.13	13	2	24.00	3.00	72.00	0.20	30	50	20
S1.14	14	1	8.00	2.50	20.00	0.10	20	50	30
S1.15	15	2	30.00	2.50	75.00	0.20	20	60	20
S1.16	16	1	6.00	2.00	12.00	0.10	10	60	20
S1.17	17	2	12.00	2.50	30.00	0.20	20	60	20
S1.18	18	1	3.00	1.50	4.50	0.15	20	50	30
S1.19	19	4	68.00	4.00	272.00	0.30	30	60	10
S1.20	20	1	4.00	2.50	10.00	0.10	20	60	20
S1.21	21	2	18.00	3.00	54.00	0.20	20	60	20
S1.22	22	1	6.00	3.00	18.00	0.10	10	60	30
S1.23	23	2	17.00	3.00	51.00	0.20	30	50	20
S1.24	24	1	12.00	2.00	24.00	0.10	10	60	30
S1.25	25	3	9.50	10.50	99.75	1.10	30	40	30
S2.1	26	2	8.00	3.00	24.00	0.15	10	50	40
S2.2	27	1	8.00	1.50	12.00	0.10	10	60	70
S2.3	28	2	3.00	3.00	9.00	0.30	20	60	20
S2.4	29	1	3.00	3.00	9.00	0.10	20	60	20
S2.5	30	2	39.00	5.50	214.50	0.40	20	60	20
S2.6	31	1	3.00	1.50	4.50	0.10	10	70	20
S2.7	32	3	7.00	3.00	21.00	0.90	30	50	20
S2.8	33	1	16.00	1.50	24.00	0.10	10	60	30
S2.9	34	3	20.00	8.00	160.00	0.60	40	40	20
S2.10	35	2	12.00	3.50	42.00	0.20	20	60	20
S2.11	36	1	8.00	2.50	20.00	0.10	10	70	20
S2.12	37	2	35.00	4.00	140.00	0.20	20	60	20
S2.13	38	1	4.00	1.50	6.00	0.10	10	60	30
S2.14	39	2	60.00	3.50	210.00	0.20	20	60	20
S2.15	40	1	21.00	3.00	63.00	0.10	10	70	20
S2.16	41	2	13.00	3.50	45.50	0.20	20	60	20
S2.17	42	1	16.00	2.00	32.00	0.15	10	70	20
S2.18	43	3	5.00	6.00	30.00	0.70	30	50	20
S2.19	44	2	12.00	3.00	36.00	0.20	30	60	10
S2.20	45	1	3.00	3.00	9.00	0.10	10	70	20
S2.21	46	2	20.00	3.00	60.00	0.25	30	50	20
S2.22	47	1	17.00	3.00	51.00	0.10	10	60	30
S2.23	48	2	21.00	4.50	94.50	0.30	20	60	20
S2.24	49	1	5.00	1.50	7.50	0.10	10	70	20
S2.25	50	3	7.00	8.00	56.00	0.10	30	60	10
S2.26	51	2	6.00	3.00	18.00	0.25	30	60	10
S2.27	52	1	4.00	1.00	4.00	0.15	10	70	20
S2.28	53	2	7.00	2.50	17.50	0.15	20	70	10
S2.29	54	1	4.00	2.50	10.00	0.10	10	70	20
S2.30	55	2	15.00	2.00	30.00	0.15	20	70	10
S2.31	56	1	2.00	1.50	3.00	0.10	20	70	10
S2.32	57	3	6.00	5.00	30.00	0.80	30	60	10
S2.33	58	1	6.00	1.50	9.00	0.10	10	70	20
S2.34	59	2	44.00	3.00	132.00	0.20	20	70	10
S2.35	60	3	6.00	3.00	18.00	1.00	40	50	10
S2.36	61	1	22.00	3.00	66.00	0.10	20	60	20
S2.37	62	2	28.00	3.00	84.00	0.20	30	60	10
S2.38	63	1	17.00	6.00	102.00	0.10	10	70	20
S2.39	64	2	20.00	2.50	50.00	0.20	20	70	10
S2.40	65	3	15.00	7.00	105.00	1.00	40	50	10
S2.41	66	2	5.00	2.50	12.50	0.15	10	70	20
S2.42	67	1	4.00	4.00	16.00	0.10	10	70	20
S2.43	68	2	15.00	5.00	75.00	0.35	30	60	10
S2.44	69	1	9.00	6.00	54.00	0.10	20	70	10
S2.45	70	2	10.00	5.00	50.00	0.20	30	60	10
S3.1	71	2	10.00	4.00	40.00	0.20	20	50	30
S3.2	72	1	45.00	4.00	180.00	0.15	20	40	40
S3.3	73	2	30.00	3.00	90.00	0.20	20	50	30
S3.4	74	1	14.00	2.00	28.00	0.15	10	60	30
S3.5	75	3	6.00	5.00	30.00	0.90	40	50	10
S3.6	76	1	6.00	2.50	15.00	0.10	20	60	20
S3.7	77	2	18.00	5.00	90.00	0.25	20	60	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S3.8	78	3	3.00	2.50	7.50	0.90	20	50	30
S3.9	79	1	6.00	1.50	9.00	0.10	10	70	20
S3.10	80	2	25.00	3.00	75.00	0.15	10	60	30
S3.11	81	1	15.00	1.00	15.00	0.15	20	70	10
S3.12	82	3	4.00	4.00	16.00	0.50	30	60	10
S3.13	83	1	3.00	1.50	4.50	0.10	10	70	20
S3.14	84	2	11.00	3.00	33.00	0.25	20	70	10
S3.15	85	1	21.00	5.00	105.00	0.10	10	70	20
S3.16	86	2	30.00	3.00	90.00	0.15	20	70	10
S3.17	87	1	35.00	3.00	105.00	0.10	10	70	20
S3.18	88	2	7.00	3.50	24.50	0.20	20	70	10
S3.19	89	1	15.00	2.00	30.00	0.15	10	70	20
S3.20	90	4	22.00	6.50	143.00	0.35	30	50	20
S3.21	91	2	9.00	3.00	27.00	0.25	30	40	30
S3.22	92	1	4.00	3.00	12.00	0.15	20	40	40
S3.23	93	2	24.00	3.00	72.00	0.20	30	50	20
S3.24	94	1	28.00	2.50	70.00	0.10	10	70	20
S3.25	95	2	21.00	2.50	52.50	0.15	10	70	20
S3.26	96	4	28.00	3.00	84.00	0.25	20	70	10
S3.27	97	1	12.00	2.50	30.00	0.10	10	70	20
S3.28	98	2	14.00	2.50	35.00	0.20	20	60	20
S3.29	99	1	3.00	2.00	6.00	0.10	10	70	20
S3.30	100	2	8.00	2.00	16.00	0.20	20	70	10
S3.31	101	1	3.00	2.00	6.00	0.10	10	70	20
S3.32	102	3	6.00	5.00	30.00	0.50	30	60	10
S3.33	103	1	38.00	2.00	76.00	0.10	10	70	20
S3.34	104	2	15.00	5.00	75.00	0.20	10	70	20
S3.35	105	1	12.00	5.50	66.00	0.10	20	60	20
S3.36	106	2	13.00	4.00	52.00	0.15	10	70	20
S3.37	107	3	15.00	5.00	75.00	1.50	30	50	20
S3.38	108	1	5.00	2.00	10.00	0.10	10	60	30
S3.39	109	2	43.00	3.00	129.00	0.20	20	60	20
S3.40	110	1	14.00	1.50	21.00	0.10	10	70	20
S3.41	111	2	13.00	2.50	32.50	0.15	10	70	20
S3.42	112	1	6.00	2.50	15.00	0.10	10	60	30
S3.43	113	2	10.00	2.50	25.00	0.15	10	70	20
S3.44	114	1	3.00	1.00	3.00	0.10	10	70	20
S3.45	115	2	8.00	3.00	24.00	0.20	10	60	30
S3.46	116	1	2.00	2.00	4.00	0.10	10	60	30
S3.47	117	2	12.00	3.00	36.00	0.20	30	60	10
S3.48	118	3	6.00	4.00	24.00	0.90	60	30	10
S3.49	119	1	16.00	1.00	16.00	0.10	10	60	30
S3.50	120	3	6.00	5.00	30.00	0.75	50	40	10
S3.51	121	1	12.00	1.00	12.00	0.10	10	60	30
S3.52	122	4	26.00	6.00	156.00	0.50	30	60	10
S3.53	123	2	15.00	3.00	45.00	0.15	20	60	20
S3.54	124	4	22.00	5.50	121.00	0.40	60	30	10
S3.55	125	2	25.00	4.00	100.00	0.20	20	70	10
S3.56	126	1	10.00	1.50	15.00	0.10	10	60	30
S3.57	127	2	38.00	3.00	114.00	0.20	10	80	10
S3.58	128	1	5.00	1.00	5.00	0.10	10	70	20
S3.59	129	3	15.00	5.00	75.00	1.00	40	50	10
S3.60	130	1	3.00	1.00	3.00	0.10	10	70	20
S3.61	131	2	24.00	4.00	96.00	0.30	30	60	10
S3.62	132	1	3.00	1.50	4.50	0.10	10	70	20
S3.63	133	2	10.00	2.00	20.00	0.15	10	70	20
S3.64	134	1	5.00	1.50	7.50	0.10	10	60	30
S3.65	135	3	6.00	3.00	18.00	1.00	40	40	20
S3.66	136	1	8.00	3.00	24.00	0.10	10	60	30
S3.67	137	2	26.00	4.50	117.00	0.30	30	60	10
S3.68	138	3	12.00	5.00	60.00	1.00	50	40	10
S3.69	139	2	25.00	4.00	100.00	0.20	20	70	10
S3.70	140	1	13.00	3.00	39.00	0.15	20	60	20
S3.71	141	2	26.00	4.00	104.00	0.20	20	70	10
S3.72	142	1	11.00	3.00	33.00	0.15	10	60	30
S3.73	143	2	7.00	3.00	21.00	0.40	30	50	20
S3.74	144	1	5.00	4.00	20.00	0.10	10	60	30

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S3.75	145	3	8.00	5.00	40.00	1.20	40	50	10
S3.76	146	2	5.00	3.00	15.00	0.30	30	50	20
S3.77	147	1	6.00	1.50	9.00	0.10	10	70	20
S3.78	148	3	8.00	4.00	32.00	1.00	60	30	10
S3.79	149	1	10.00	3.00	30.00	0.15	20	60	20
S3.80	150	2	44.00	2.00	88.00	0.20	20	70	10
S3.81	151	1	4.00	1.00	4.00	0.10	10	60	30
S3.82	152	2	18.00	3.00	54.00	0.25	20	60	20
S3.83	153	1	30.00	1.50	45.00	0.15	10	60	30
S4.1	154	3	10.00	7.00	70.00	1.00	40	50	10
S4.2	155	1	10.00	1.50	15.00	0.10	10	60	30
S4.3	156	2	10.00	4.00	40.00	0.20	30	50	20
S4.4	157	1	3.00	3.00	9.00	0.10	20	70	10
S4.5	158	2	25.00	3.50	87.50	0.20	20	60	20
S4.6	159	3	4.00	5.00	20.00	0.70	40	50	10
S4.7	160	2	11.00	3.00	33.00	0.25	20	60	20
S4.8	161	1	22.00	3.00	66.00	0.10	10	70	20
S4.9	162	2	7.00	3.50	24.50	0.20	30	50	20
S4.10	163	3	8.00	6.50	52.00	1.70	50	40	10
S4.11	164	1	15.00	1.50	22.50	0.15	20	60	20
S4.12	165	3	20.00	5.00	100.00	1.00	60	30	10
S4.13	166	2	12.00	3.50	42.00	0.30	30	60	10
S4.14	167	1	4.00	1.00	4.00	0.15	30	50	20
S4.15	168	2	26.00	2.00	52.00	0.20	20	60	20
S4.16	169	1	4.00	3.00	12.00	0.10	10	70	20
S4.17	170	2	14.00	3.00	42.00	0.20	10	70	20
S4.18	171	1	5.00	3.50	17.50	0.10	10	60	30
S4.19	172	2	20.00	3.00	60.00	0.25	20	60	20
S4.20	173	1	5.00	1.00	5.00	0.10	20	70	10
S4.21	174	4	8.00	3.00	24.00	0.40	20	70	10
S4.22	175	1	10.00	1.50	15.00	0.10	10	70	20
S4.23	176	2	9.00	3.00	27.00	0.20	10	70	20
S4.24	177	1	8.00	2.50	20.00	0.15	10	70	20
S4.25	178	2	15.00	3.00	45.00	0.20	10	60	30
S4.26	179	1	8.00	1.00	8.00	0.15	10	60	30
S4.27	180	4	13.00	4.00	52.00	0.40	30	60	10
S4.28	181	1	26.00	2.00	52.00	0.10	10	60	30
S4.29	182	2	18.00	2.00	36.00	0.20	30	60	10
S4.30	183	1	40.00	1.50	60.00	0.10	10	70	20
S4.31	184	2	38.00	4.00	152.00	0.30	30	50	20
S4.32	185	1	9.00	3.00	27.00	0.10	20	60	20
S4.33	186	2	13.00	3.50	45.50	0.25	20	60	20
S4.34	187	1	10.00	3.00	30.00	0.10	10	60	30
S4.35	188	2	36.00	3.00	108.00	0.40	20	60	20
S4.36	189	1	6.00	1.50	9.00	0.10	20	70	10
S4.37	190	3	12.00	6.00	72.00	1.50	60	30	10
S4.38	191	1	16.00	2.00	32.00	0.15	10	60	30
S4.39	192	2	15.00	2.00	30.00	0.20	20	60	20
S4.40	193	4	20.00	2.50	50.00	0.30	30	60	10
S4.41	194	1	57.00	4.50	256.50	0.15	20	60	20
S4.42	195	2	25.00	3.00	75.00	0.35	20	60	20
S4.43	196	4	23.00	5.00	115.00	0.50	40	50	10
S4.44	197	1	13.00	3.00	39.00	0.10	10	60	30
S4.45	198	4	36.00	5.00	180.00	0.50	30	60	10
S4.46	199	1	9.00	3.00	27.00	0.15	10	40	50
S4.47	200	2	7.00	2.50	17.50	0.25	10	50	40
S5.1	201	1	18.00	4.50	81.00	0.10	10	50	40
S5.2	202	2	30.00	3.50	105.00	0.20	20	40	40
S5.3	203	1	1.00	2.00	2.00	0.10	10	70	20
S5.4	204	2	12.00	3.00	36.00	0.20	20	60	20
S5.5	205	1	13.00	3.50	45.50	0.10	10	60	30
S5.6	206	2	14.00	3.00	42.00	0.25	10	70	20
S5.7	207	1	8.00	1.50	12.00	0.10	10	60	30
S5.8	208	2	9.00	1.50	13.50	0.20	10	70	20
S5.9	209	3	2.00	4.00	8.00	0.50	30	50	20
S5.10	210	1	5.00	1.00	5.00	0.10	20	60	20
S5.11	211	3	7.00	4.00	28.00	0.70	40	50	10

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S5.12	212	4	7.00	3.00	21.00	0.30	20	60	20
S5.13	213	3	7.00	4.00	28.00	1.00	40	50	10
S5.14	214	1	11.00	3.00	33.00	0.10	10	60	30
S5.15	215	2	19.00	3.00	57.00	0.20	20	60	20
S5.16	216	1	2.00	2.00	4.00	0.10	10	60	30
S5.17	217	2	3.00	2.00	6.00	0.15	10	70	20
S5.18	218	1	2.00	3.00	6.00	0.10	10	60	30
S5.19	219	2	7.00	2.50	17.50	0.15	10	70	20
S5.20	220	1	8.00	3.50	28.00	0.10	10	60	30
S5.21	221	2	10.00	2.50	25.00	0.20	20	60	20
S5.22	222	3	10.00	5.00	50.00	0.90	50	40	10
S5.23	223	2	44.00	2.00	88.00	0.20	20	60	20
S5.24	224	1	25.00	2.00	50.00	0.10	10	70	20
S5.25	225	2	7.00	2.00	14.00	0.20	20	60	20
S5.26	226	3	7.00	6.00	42.00	0.80	40	50	10
S5.27	227	1	28.00	1.00	28.00	0.10	10	60	30
S5.28	228	2	22.00	3.00	66.00	0.25	20	60	20
S5.29	229	1	2.00	2.50	5.00	0.10	10	70	20
S5.30	230	2	26.00	2.00	52.00	0.25	20	60	20
S5.31	231	1	11.00	1.50	16.50	0.10	10	70	20
S5.32	232	2	28.00	2.00	56.00	0.20	20	60	20
S5.33	233	1	4.00	2.00	8.00	0.10	10	60	30
S5.34	234	2	28.00	2.00	56.00	0.20	20	60	20
S5.35	235	1	17.00	1.00	17.00	0.10	10	80	10
S5.36	236	2	27.00	2.00	54.00	0.20	20	60	20
S5.37	237	1	5.00	2.00	10.00	0.10	10	70	20
S5.38	238	2	25.00	2.50	62.50	0.20	20	60	20
S5.39	239	1	6.00	1.50	9.00	0.10	10	60	30
S5.40	240	2	31.00	2.00	62.00	0.20	10	70	20
S5.41	241	1	6.00	2.00	12.00	0.10	10	70	20
S5.42	242	3	10.00	5.00	50.00	1.20	50	40	10
S5.43	243	1	9.00	3.00	27.00	0.10	10	60	30
S5.44	244	4	12.00	5.00	60.00	0.40	60	30	10
S5.45	245	2	8.00	2.00	16.00	0.20	30	60	10
S5.46	246	1	2.00	1.00	2.00	0.10	10	60	30
S5.47	247	2	15.00	2.00	30.00	0.20	20	60	20
S5.48	248	1	26.00	1.50	39.00	0.10	10	60	30
S5.49	249	4	3.00	2.50	7.50	0.30	20	60	20
S5.50	250	1	12.00	1.50	18.00	0.10	10	70	20
S5.51	251	2	7.00	3.00	21.00	0.15	10	60	30
S5.52	252	1	14.00	4.00	56.00	0.10	10	50	40
S5.53	253	2	15.00	2.50	37.50	0.20	20	60	20
S5.54	254	3	12.00	4.00	48.00	1.00	60	30	10
S5.55	255	1	18.00	1.50	27.00	0.10	10	70	20
S5.56	256	2	7.00	3.00	21.00	0.25	20	60	20
S5.57	257	1	8.00	3.50	28.00	0.10	10	60	30
S5.58	258	2	6.00	2.00	12.00	0.30	10	60	30
S5.59	259	1	1.00	2.00	2.00	0.10	10	60	30
S5.60	260	2	14.00	3.00	42.00	0.20	10	60	30
S5.61	261	1	8.00	3.00	24.00	0.10	10	60	30
S5.62	262	2	20.00	2.00	40.00	0.25	20	60	20
S5.63	263	1	4.00	1.00	4.00	0.10	10	60	30
S5.64	264	2	5.00	1.00	5.00	0.15	10	60	30
S5.65	265	1	6.00	1.50	9.00	0.10	10	50	40
S5.66	266	4	10.00	5.00	50.00	0.70	50	30	20
S5.67	267	1	3.00	1.00	3.00	0.10	10	70	20
S5.68	268	2	18.00	1.50	27.00	0.20	10	70	20
S5.69	269	3	8.00	5.00	40.00	1.20	60	30	10
S5.70	270	1	2.00	1.00	2.00	0.10	10	70	20
S5.71	271	2	5.00	1.00	5.00	0.15	10	70	20
S5.72	272	1	14.00	1.50	21.00	0.10	10	60	30
S5.73	273	2	17.00	2.00	34.00	0.15	10	60	30
S6.1	274	1	10.00	1.50	15.00	0.10	10	60	30
S6.2	275	4	3.00	3.50	10.50	0.60	30	50	20
S6.3	276	1	12.00	2.00	24.00	0.10	10	60	30
S6.4	277	2	10.00	3.00	30.00	0.25	20	60	20
S6.5	278	1	4.00	1.50	6.00	0.10	10	60	30

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S6.6	279	2	16.00	2.50	40.00	0.20	20	60	20
S6.7	280	1	3.00	1.00	3.00	0.10	10	60	30
S6.8	281	2	13.00	2.00	26.00	0.15	20	60	20
S6.9	282	1	21.00	3.00	63.00	0.10	10	60	30
S6.10	283	2	8.00	3.00	24.00	0.20	10	60	30
S6.11	284	1	5.00	3.00	15.00	0.10	10	50	40
S6.12	285	2	7.00	2.00	14.00	0.20	10	60	30
S6.13	286	1	5.00	1.50	7.50	0.10	10	60	30
S6.14	287	2	8.00	1.50	12.00	0.20	10	60	30
S6.15	288	1	5.00	1.00	5.00	0.10	10	60	30
S6.16	289	2	20.00	3.50	70.00	0.25	20	60	20
S6.17	290	1	1.00	3.00	3.00	0.10	10	50	40
S6.18	291	2	18.00	2.00	36.00	0.25	10	70	20
S6.19	292	1	16.00	2.50	40.00	0.10	10	50	40
S6.20	293	2	20.00	2.00	40.00	0.20	20	60	20
S6.21	294	3	6.00	5.00	30.00	0.80	60	40	10
S6.22	295	1	36.00	3.00	108.00	0.10	10	70	20
S6.23	296	2	36.00	4.00	144.00	0.25	10	60	30
S6.24	297	1	4.00	1.00	4.00	0.10	10	50	30
S6.25	298	2	10.00	2.00	20.00	0.15	10	50	40
S6.26	299	1	4.00	2.00	8.00	0.10	10	50	40
S6.27	300	2	15.00	2.00	30.00	0.25	10	60	30
S6.28	301	1	5.00	2.00	10.00	0.10	10	50	40
S6.29	302	2	32.00	2.00	64.00	0.25	10	60	30
S6.30	303	1	6.00	1.50	9.00	0.10	10	50	40
S6.31	304	2	7.00	2.00	14.00	0.20	10	60	30
S6.32	305	1	3.00	3.00	9.00	0.10	10	70	20
S6.33	306	2	5.00	2.00	10.00	0.20	10	70	20
S6.34	307	1	18.00	4.00	72.00	0.10	10	60	30
S6.35	308	2	16.00	3.00	48.00	0.15	10	70	20
S6.36	309	1	15.00	3.00	45.00	0.10	10	50	40
S6.37	310	4	7.00	4.00	28.00	0.60	30	50	20
S6.38	311	1	4.00	1.50	6.00	0.10	10	60	30
S6.39	312	4	16.00	2.50	40.00	0.35	20	60	20
S6.40	313	2	12.00	2.00	24.00	0.20	10	70	20
S6.41	314	1	14.00	3.00	42.00	0.10	10	50	40
S6.42	315	2	20.00	2.00	40.00	0.25	10	60	30
S6.43	316	1	8.00	2.00	16.00	0.10	10	50	40
S6.44	317	2	7.00	3.50	24.50	0.20	10	50	40
S6.45	318	1	5.00	2.50	12.50	0.15	10	50	40
S6.46	319	2	16.00	3.50	56.00	0.30	10	50	40
S6.47	320	1	4.00	2.00	8.00	0.10	10	60	30
S6.48	321	2	10.00	3.00	30.00	0.20	10	60	30
S6.49	322	1	26.00	2.00	52.00	0.10	10	60	30
S6.50	323	3	5.00	5.00	25.00	0.70	30	50	20
S6.51	324	1	38.00	1.00	38.00	0.15	10	60	30
S6.52	325	3	5.00	5.00	25.00	1.30	40	40	20
S6.53	326	1	3.00	2.00	6.00	0.10	10	60	30
S6.54	327	3	6.00	5.00	30.00	1.20	40	40	20
S6.55	328	4	15.00	2.50	37.50	0.40	20	60	20
S6.56	329	1	15.00	2.00	30.00	0.10	10	60	30
S6.57	330	2	6.00	2.00	12.00	0.15	10	60	30
S6.58	331	1	20.00	1.50	30.00	0.10	10	50	40
S6.59	332	2	15.00	3.00	45.00	0.20	10	50	40
S6.60	333	1	5.00	1.00	5.00	0.10	10	50	40
S6.61	334	2	14.00	2.00	28.00	0.25	10	60	30
S6.62	335	1	14.00	2.00	28.00	0.10	10	60	30
S6.63	336	2	47.00	3.00	141.00	0.25	10	60	30
S6.64	337	1	3.00	3.00	9.00	0.10	10	70	20
S6.65	338	2	31.00	2.00	62.00	0.20	10	60	30
S6.66	339	1	5.00	2.00	10.00	0.10	10	70	20
S6.67	340	2	23.00	3.00	69.00	0.25	10	70	20
S6.68	341	1	4.00	1.50	6.00	0.10	10	70	20
S6.69	342	2	26.00	3.00	78.00	0.30	30	50	20
S6.70	343	1	10.00	3.00	30.00	0.10	10	60	30
S6.71	344	4	17.00	4.00	68.00	0.60	60	30	10
S6.72	345	2	5.00	1.50	7.50	0.20	10	60	30

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S6.73	346	1	17.00	4.00	68.00	0.10	10	50	40
S6.74	347	2	21.00	2.50	52.50	0.20	10	70	20
S6.75	348	1	2.00	2.00	4.00	0.10	10	60	30
S6.76	349	2	23.00	2.00	46.00	0.25	30	50	20
S6.77	350	1	6.00	1.00	6.00	0.15	50	30	20
S6.78	351	2	5.00	1.50	7.50	0.25	50	30	20
S6.79	352	1	15.00	1.00	15.00	0.10	10	60	30
S6.80	353	2	21.00	2.00	42.00	0.20	10	60	30
S6.81	354	3	4.00	5.00	20.00	0.50	60	30	10
S6.82	355	4	5.00	3.00	15.00	0.40	50	30	20
S6.83	356	1	7.00	1.00	7.00	0.10	10	60	30
S6.84	357	3	6.00	2.50	15.00	0.60	30	50	20
S6.85	358	1	1.00	1.00	1.00	0.10	10	60	30
S6.86	359	3	12.00	3.00	36.00	0.70	30	60	30
S6.87	360	2	10.00	2.00	20.00	0.20	10	70	20
S6.88	361	1	11.00	1.50	16.50	0.10	10	60	30
S6.89	362	2	14.00	2.50	35.00	0.30	30	50	20
S6.90	363	1	8.00	0.50	4.00	0.10	10	50	30
S6.91	364	2	40.00	2.50	100.00	0.35	10	70	20
S6.92	365	1	5.00	1.00	5.00	0.10	10	60	30
S6.93	366	2	16.00	2.00	32.00	0.20	10	60	30
S7.1	367	4	12.00	3.00	36.00	0.40	30	50	20
S7.2	368	1	1.00	0.50	0.50	0.10	10	70	20
S7.3	369	4	20.00	4.50	90.00	0.50	30	50	20
S7.4	370	1	14.00	4.00	56.00	0.10	10	60	30
S7.5	371	2	60.00	3.50	210.00	0.30	10	60	30
S7.6	372	1	4.00	1.00	4.00	0.10	10	60	30
S7.7	373	4	11.00	3.00	33.00	0.30	30	50	20
S7.8	374	1	2.00	1.00	2.00	0.10	10	70	20
S7.9	375	4	4.00	2.00	8.00	0.30	20	60	20
S7.10	376	1	4.00	1.00	4.00	0.10	10	60	30
S7.11	377	3	5.00	6.00	30.00	1.30	40	50	10
S7.12	378	4	15.00	4.00	60.00	0.80	30	50	20
S7.13	379	2	18.00	3.00	54.00	0.25	20	50	30
S7.14	380	1	3.00	1.00	3.00	0.15	50	30	20
S7.15	381	4	13.00	3.00	39.00	0.30	40	50	10
S7.16	382	1	10.00	2.00	20.00	0.10	10	60	30
S7.17	383	2	47.00	3.00	141.00	0.20	10	60	30
S7.18	384	4	10.00	3.50	35.00	0.40	40	50	10
S7.19	385	1	12.00	1.00	12.00	0.10	40	40	20
S7.20	386	2	18.00	3.00	54.00	0.20	10	60	30
S7.21	387	1	10.00	3.00	30.00	0.10	10	50	40
S7.22	388	2	12.00	4.50	54.00	0.25	20	60	20
S7.23	389	4	28.00	4.00	112.00	0.50	60	30	10
S7.24	390	2	17.00	2.00	34.00	0.20	30	50	20
S7.25	391	3	4.00	4.00	16.00	0.90	60	30	10
S7.26	392	2	5.00	1.00	5.00	0.30	70	20	10
S7.27	393	1	10.00	1.00	10.00	0.10	30	50	20
S7.28	394	2	7.00	2.00	14.00	0.15	20	60	20
S7.29	395	1	7.00	2.50	17.50	0.10	10	70	20
S7.30	396	2	20.00	2.00	40.00	0.35	10	70	20
S7.31	397	1	12.00	1.00	12.00	0.10	10	60	30
S7.32	398	2	22.00	3.00	66.00	0.20	30	50	10
S7.33	399	4	15.00	3.00	45.00	0.70	40	50	10
S7.34	400	2	25.00	2.50	62.50	0.20	20	60	20
S7.35	401	1	10.00	3.00	30.00	0.10	10	50	40
S7.36	402	2	9.00	1.50	13.50	0.25	10	60	30
S7.37	403	1	9.00	3.00	27.00	0.15	10	50	40
S7.38	404	3	12.00	13.00	156.00	2.50	60	30	10
S8.1	405	4	10.00	30.00	300.00	0.30	20	60	20
S8.2	406	1	1.00	1.00	1.00	0.10	10	60	30
S8.3	407	2	9.00	2.00	18.00	0.20	10	60	30
S8.4	408	1	1.00	1.50	1.50	0.10	10	60	30
S8.5	409	2	4.00	2.00	8.00	0.20	10	60	30
S8.6	410	1	8.00	4.50	36.00	0.10	10	50	40
S8.7	411	2	32.00	3.50	112.00	0.25	10	60	30
S8.8	412	1	7.00	4.00	28.00	0.10	10	50	40

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S8.9	413	2	8.00	2.00	16.00	0.20	10	60	30
S8.10	414	1	5.00	2.00	10.00	0.10	10	60	30
S8.11	415	2	9.00	2.50	22.50	0.30	10	60	30
S8.12	416	1	3.00	1.00	3.00	0.10	10	60	30
S8.13	417	2	18.00	2.50	45.00	0.30	20	60	20
S8.14	418	1	3.00	3.00	9.00	0.10	10	60	30
S8.15	419	2	11.00	2.50	27.50	0.30	10	60	30
S8.16	420	1	3.00	3.00	9.00	0.10	10	60	30
S8.17	421	4	30.00	4.50	135.00	0.60	10	50	10
S8.18	422	1	3.00	2.00	6.00	0.10	10	50	40
S8.19	423	2	13.00	2.00	26.00	0.20	20	50	30
S8.20	424	1	5.00	3.00	15.00	0.10	10	60	30
S8.21	425	2	11.00	2.50	27.50	0.20	20	60	20
S8.22	426	4	24.00	4.00	96.00	0.80	40	50	10
S8.23	427	1	8.00	2.00	16.00	0.10	20	50	30
S8.24	428	4	110.00	4.50	495.00	0.65	40	50	10
S8.25	429	2	5.00	2.50	12.50	0.20	20	60	20
S8.26	430	1	1.00	1.00	1.00	0.10	10	70	20
S8.27	431	4	15.00	3.00	45.00	0.50	40	40	20
S8.28	432	1	3.00	3.00	9.00	0.10	10	60	30
S8.29	433	2	7.00	3.00	21.00	0.20	10	60	30
S8.30	434	4	30.00	4.00	120.00	0.60	70	20	10
S8.31	435	2	5.00	2.00	10.00	0.25	20	60	20
S8.32	436	1	17.00	2.00	34.00	0.10	20	60	20
S8.33	437	2	17.00	1.00	17.00	0.20	20	60	20
S8.34	438	1	3.00	1.00	3.00	0.10	20	70	10
S8.35	439	3	6.00	4.00	24.00	1.00	60	30	10
S8.36	440	2	10.00	1.50	15.00	0.20	40	40	20
S8.37	441	1	1.00	1.00	1.00	0.10	10	50	40
S8.38	442	2	41.00	1.50	61.50	0.20	70	20	10
S8.39	443	1	2.00	1.00	2.00	0.10	70	10	20
S8.40	444	2	13.00	2.00	26.00	0.20	60	20	20
S8.41	445	1	2.00	1.00	2.00	0.10	50	10	40
S8.42	446	2	15.00	2.50	37.50	0.20	50	20	30
S8.43	447	1	12.00	1.50	18.00	0.10	10	60	30
S8.44	448	2	10.00	2.50	25.00	0.30	40	50	10
S8.45	449	1	13.00	1.00	13.00	0.10	20	60	20
S8.46	450	2	15.00	3.00	45.00	0.35	20	60	20
S8.47	451	1	8.00	1.00	8.00	0.10	10	60	30
S8.48	452	3	20.00	6.00	120.00	1.20	60	30	10
S8.49	453	2	20.00	1.50	30.00	0.25	50	30	20
S8.50	454	1	1.00	1.00	1.00	0.10	20	50	30
S8.51	455	3	6.00	4.00	24.00	0.60	40	50	10
S8.52	456	2	8.00	1.00	8.00	0.20	50	20	30
S8.53	457	1	7.00	4.00	28.00	0.10	10	50	40
S8.54	458	2	16.00	2.50	40.00	0.25	10	60	30
S8.55	459	4	16.00	3.00	48.00	0.50	40	40	20
S8.56	460	1	10.00	2.00	20.00	0.10	10	70	20
S8.57	461	2	24.00	2.50	60.00	0.30	10	70	20
S8.58	462	1	8.00	2.00	16.00	0.10	20	60	20
S8.59	463	2	5.00	2.00	10.00	0.20	20	60	20
S8.60	464	1	5.00	1.00	5.00	0.10	20	40	40
S8.61	465	4	20.00	3.50	70.00	1.00	60	30	10
S8.62	466	2	11.00	2.00	22.00	0.25	30	50	20
S8.63	467	1	5.00	4.50	22.50	0.10	10	60	30
S8.64	468	4	39.00	4.00	156.00	0.40	30	50	20
S8.65	469	1	10.00	1.50	15.00	0.10	10	60	30
S8.66	470	4	6.00	4.00	24.00	0.20	20	60	20
S8.67	471	1	8.00	2.00	16.00	0.10	10	50	40
S8.68	472	2	20.00	2.50	50.00	0.15	20	60	20
S8.69	473	1	5.00	3.00	15.00	0.10	10	60	30
S8.70	474	2	36.00	2.50	90.00	0.20	20	60	20
S8.71	475	1	20.00	1.50	30.00	0.15	10	60	30
S8.72	476	2	9.00	1.50	13.50	0.15	10	60	30
S8.73	477	3	7.00	4.00	28.00	0.60	40	40	20
S8.74	478	2	6.00	1.00	6.00	0.15	10	70	20
S8.75	479	3	12.00	4.00	48.00	0.60	40	40	20

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S8.76	480	1	3.00	1.00	3.00	0.10	10	50	40
S8.77	481	2	27.00	2.50	67.50	0.20	40	40	20
S8.78	482	1	15.00	3.00	45.00	0.10	10	50	40
S8.79	483	2	17.00	2.50	42.50	0.20	20	50	30
S8.80	484	1	13.00	1.50	19.50	0.10	10	60	30
S8.81	485	2	5.00	1.50	7.50	0.30	10	60	30
S8.82	486	1	4.00	2.00	8.00	0.10	10	60	30
S8.83	487	2	10.00	1.00	10.00	0.15	20	60	20
S8.84	488	4	33.00	3.50	115.50	0.40	50	40	10
S8.85	489	1	2.00	1.00	2.00	0.10	10	70	20
S8.86	490	2	5.00	1.50	7.50	0.20	20	60	20
S8.87	491	1	17.00	1.00	17.00	0.10	10	60	30
S8.88	492	2	6.00	1.50	9.00	0.15	10	60	30
S8.89	493	1	10.00	2.00	20.00	0.10	10	60	30
S8.90	494	4	15.00	3.00	45.00	0.35	40	40	20
S8.91	495	3	7.00	2.00	14.00	0.55	40	30	30
S8.92	496	4	50.00	5.00	250.00	0.65	60	30	10
S8.93	497	2	45.00	2.50	112.50	0.25	20	60	20
S8.94	498	1	10.00	1.00	10.00	0.10	10	50	40
S8.95	499	4	42.00	3.00	126.00	0.50	40	40	20
S8.96	500	1	3.00	1.00	3.00	0.10	10	70	20
S8.97	501	4	10.00	2.50	25.00	0.50	40	40	20
S8.98	502	1	9.00	1.00	9.00	0.10	10	60	30
S8.99	503	2	16.00	2.00	32.00	0.15	20	60	20
S8.100	504	1	3.00	1.00	3.00	0.10	10	60	30
S8.101	505	4	8.00	4.00	32.00	0.30	30	50	20
S8.102	506	1	1.00	1.00	1.00	0.10	10	50	40
S8.103	507	4	10.00	4.00	40.00	0.50	50	30	20
S8.104	508	1	20.00	1.00	20.00	0.10	10	50	40
S8.105	509	2	8.00	2.00	16.00	0.20	20	60	20
S8.106	510	4	14.00	3.50	49.00	0.60	50	40	10
S8.107	511	2	10.00	3.00	30.00	0.30	10	60	30
S8.108	512	1	24.00	1.00	24.00	0.10	10	60	30
S8.109	513	4	31.00	5.00	155.00	0.30	30	50	20
S9.1	514	4	20.00	4.00	80.00	0.30	20	60	20
S9.2	515	2	18.00	1.50	27.00	0.15	10	60	30
S9.3	516	4	13.00	4.00	52.00	0.50	30	50	20
S9.4	517	1	2.00	3.00	6.00	0.10	20	50	30
S9.5	518	3	10.00	3.00	30.00	0.70	20	70	10
S9.6	519	1	8.00	3.00	24.00	0.10	10	60	30
S9.7	520	4	7.00	2.00	14.00	0.30	30	50	20
S9.8	521	1	1.00	0.50	0.50	0.10	10	50	40
S9.9	522	4	12.00	3.00	36.00	0.30	40	50	10
S9.10	523	1	7.00	0.50	3.50	0.10	10	60	30
S9.11	524	4	26.00	3.00	78.00	0.30	30	50	20
S9.12	525	1	3.00	0.50	1.50	0.10	30	50	20
S9.13	526	4	38.00	2.50	95.00	0.30	30	50	20
S9.14	527	2	10.00	0.50	5.00	0.20	30	50	20
S9.15	528	3	15.00	4.00	60.00	1.50	30	50	20
S9.16	529	4	16.00	3.00	48.00	0.40	40	40	20
S9.17	530	2	6.00	1.00	6.00	0.20	30	40	30
S9.18	531	4	50.00	4.00	200.00	0.40	40	40	20
S9.19	532	1	5.00	0.50	2.50	0.10	30	60	10
S9.20	533	4	70.00	3.00	210.00	0.35	40	50	10
S9.21	534	1	4.00	0.50	2.00	0.10	20	70	10
S9.22	535	4	10.00	1.50	15.00	0.25	40	50	10
S9.23	536	1	3.00	0.50	1.50	0.10	20	60	20
S9.24	537	4	28.00	3.00	84.00	0.30	40	40	20
S9.25	538	1	8.00	0.50	4.00	0.10	30	50	20
S9.26	539	4	18.00	3.00	54.00	0.25	40	40	20
S9.27	540	1	3.00	2.00	6.00	0.10	20	60	20
S9.28	541	4	44.00	3.00	132.00	0.40	40	40	20
S9.29	542	1	8.00	1.00	8.00	0.10	20	50	30
S9.30	543	3	22.00	5.00	110.00	2.00	50	40	10
S10.1	544	4	30.00	3.00	90.00	0.50	40	40	20
S10.2	545	1	2.00	0.50	1.00	0.10	10	70	20
S10.3	546	3	4.00	4.00	16.00	0.45	20	50	30

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	% Sub Fine	% Sub Gravel	% Sub Bld.
S10.4	547	1	2.00	0.50	1.00	0.10	20	60	20
S10.5	548	4	10.00	3.00	30.00	0.40	30	50	20
S10.6	549	2	2.00	1.00	2.00	0.10	30	50	20
S10.7	550	3	10.00	5.00	50.00	0.85	30	50	20
S10.8	551	4	12.00	1.50	18.00	0.25	30	50	20
S10.9	552	1	4.00	1.00	4.00	0.10	10	70	20
S10.10	553	4	32.00	4.00	128.00	0.50	40	40	20
S10.11	554	1	7.00	3.00	21.00	0.10	30	60	10
S10.11	555	4	6.00	4.00	24.00	0.25	30	60	10

Appendix C

Detailed Habitat Inventory (1990) Data Collected in Coghlan Creek (C) and the Salmon River (S).

Unit 1 = Riffles, Unit 2 = Glides, Unit 3 = Pools, Unit 4 = Sloughs

Length, Wetted Width, Depth, and Channel Width - measured in meters (m)

Area, Instream Log, Instream Boulder, Instream Vegetation, Overstream Vegetation, and Cutbank - measured in square meters (m^2)

Volume - measured in cubic meters (m^3)

Velocity - measured in meters per second (m\s)

Temperature - measured in degrees celsius (C^o)

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	Volume	Channel Width	Vel.	Thalweg Depth	% Fine	% Sm Gravel	% Lg Gravel	% Cobble	% Boulder
C7.5	212	1	10.4	2.9	30.2	0.07	2.1	4.2	0.36	0.15	20	70	10	0	0
C8.114	429	1	10.8	1.1	11.9	0.09	1.1	7.1	0.28	0.12	5	20	45	25	5
C8.105	420	1	12.8	2.6	33.3	0.07	2.3	5.5	0.24	0.10	5	25	40	20	10
C8.61	376	1	6.2	3.4	21.1	0.06	1.3	6.8	0.23	0.10	10	30	35	20	5
C8.52	367	1	16.9	2.5	42.3	0.09	3.8	8.6	0.28	0.28	10	40	30	15	5
C7.104	311	1	3.8	3.5	13.3	0.13	1.7	5.9	0.44	0.27	5	35	30	20	10
C7.60	267	1	4.8	1.8	8.6	0.07	0.6	6.2	0.32	0.11	10	50	35	5	0
C7.53	260	1	4.8	1.8	8.6	0.10	0.9	8.2	0.33	0.24	15	70	10	5	0
C1.7	7	1	6.3	4.0	25.2	0.15	3.8	6.3	0.50	0.35	5	40	40	10	5
C4.72	125	1	21.5	5.1	109.7	0.16	17.6	8.3	0.48	0.40	10	30	20	25	15
C3.24	52	1	3.7	3.1	11.5	0.37	4.3	5.0	0.30	0.25	5	65	25	5	0
C4.53	106	1	7.8	6.1	47.6	0.09	4.3	7.4	0.34	0.16	5	30	40	20	5
C7.48	255	2	9.8	3.7	36.3	0.33	12.0	6.2	0.05	0.61	35	55	10	0	0
C8.56	371	2	9.4	2.7	25.4	0.16	4.1	5.7	0.13	0.28	10	35	35	15	5
C4.6	59	2	15.9	4.4	70.0	0.32	22.4	5.9	0.10	0.65	60	25	10	5	0
C8.35	350	2	5.8	2.3	13.3	0.21	2.8	6.1	0.11	0.33	15	30	35	20	0
C4.17	70	2	10.5	3.3	34.6	0.20	6.9	4.8	0.20	0.56	10	60	25	5	0
C5.34	169	2	34.3	2.8	96.0	0.15	14.4	5.7	0.21	0.43	15	30	40	15	0
C7.72	279	2	9.9	1.8	17.8	0.11	2.0	8.5	0.19	0.17	20	45	30	5	0
C8.99	414	2	36.4	3.4	123.8	0.17	21.0	6.4	0.12	0.50	15	35	30	15	5
C4.68	121	2	11.8	4.8	56.6	0.14	7.9	8.1	0.32	0.33	20	40	20	10	10
C7.6	213	2	31.9	3.2	102.1	0.09	9.2	6.1	0.32	0.22	20	60	20	0	0

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	Volume	Channel Width	Vel.	Thalweg Depth	% Fine	% Sm Gravel	% Lg Gravel	% Cobble	% Boulder
C6.36	206	2	19.2	4.9	94.1	0.18	16.9	9.9	0.12	0.35	30	15	20	20	15
C2.4	12	2	4.8	3.2	15.4	0.24	3.7	8.9	0.27	0.35	5	25	35	25	10
C8.34	349	3	4.3	3.6	15.5	0.39	6.0	6.0	0.00	0.60	15	30	40	15	0
C6.15	185	3	7.8	3.9	30.4	0.36	10.9	5.3	0.00	0.69	20	30	30	20	0
C4.28	81	3	5.2	3.3	17.2	0.34	5.8	5.7	0.00	0.57	40	40	10	10	0
C2.10	18	3	7.2	6.2	44.6	0.49	21.9	7.7	0.00	0.75	35	40	20	5	0
C8.2	317	3	7.8	5.1	39.8	0.54	21.5	6.6	0.00	0.95	35	60	5	0	0
C7.63	270	3	7.8	3.5	27.3	0.33	9.0	7.2	0.00	0.80	35	50	10	5	0
C8.106	421	4	13.2	2.9	38.3	0.26	10.0	6.1	0.00	0.45	10	30	30	25	5
C4.73	126	4	9.8	3.8	37.2	0.23	8.6	11.4	0.09	0.40	25	55	15	5	0
C8.101	416	4	30.9	3.9	120.5	0.36	43.4	8.7	0.00	0.63	25	20	35	15	5
C8.39	354	4	8.7	4.5	39.2	0.30	11.8	11.6	0.00	0.58	20	25	35	20	0
C7.18	225	4	16.3	3.4	55.4	0.27	15.0	5.4	0.06	0.44	30	45	20	5	0
C7.74	281	4	11.5	3.6	41.4	0.39	16.1	6.8	0.00	0.72	35	35	20	10	0
S5.1	633	1	18.7	8.5	159.0	0.11	17.5	12.5	0.29	0.22	10	20	30	30	10
S9.29	974	1	7.8	2.1	16.4	0.05	0.8	12.4	0.18	0.10	15	35	35	15	0
S8.85	921	1	3.2	2.3	7.4	0.04	0.3	13.2	0.26	0.08	5	40	30	25	0
S8.39	875	1	3.1	2.0	6.2	0.08	0.5	11.7	0.46	0.15	70	5	15	10	0
S7.19	817	1	17.7	1.8	31.9	0.09	2.9	13.8	0.14	0.19	40	20	30	5	5
S6.56	761	1	18.5	3.7	68.5	0.07	4.8	10.9	0.33	0.15	10	30	40	15	5
S6.30	735	1	7.1	2.9	20.6	0.08	1.6	13.5	0.24	0.18	5	20	30	35	10
S6.9	714	1	26.5	5.0	132.5	0.11	14.6	11.0	0.16	0.30	10	15	25	30	20
S5.7	639	1	10.6	2.9	30.7	0.10	3.1	29.9	0.44	0.17	5	30	40	25	0
S1.16	448	1	6.6	3.8	25.1	0.10	2.5	10.6	0.75	0.16	5	35	50	10	0
S2.31	488	1	4.6	4.8	22.1	0.20	4.4	12.9	0.53	0.40	20	50	25	5	0
S3.38	540	1	9.3	3.9	36.3	0.17	6.2	15.8	0.34	0.30	5	30	50	15	0
S4.35	620	2	39.9	5.6	223.4	0.34	76.0	16.1	0.10	1.20	20	25	30	25	0
S6.25	730	2	11.8	3.8	44.8	0.14	6.3	11.0	0.14	0.23	5	15	30	30	20
S9.14	959	2	11.7	1.2	14.0	0.11	1.5	11.6	0.23	0.18	10	20	40	30	0
S8.54	890	2	16.5	3.6	59.4	0.16	9.5	13.7	0.10	0.48	10	25	35	30	0
S8.11	847	2	10.9	2.9	31.6	0.36	11.4	10.5	0.14	0.65	15	35	35	15	0
S2.39	496	2	22.2	6.0	133.2	0.15	20.0	14.4	0.25	0.26	10	40	40	10	0
S7.13	811	2	16.2	3.3	53.5	0.16	8.6	8.1	0.09	0.45	20	35	25	20	0
S4.13	598	2	10.1	4.2	42.4	0.43	18.2	13.6	0.15	0.87	35	40	20	5	0
S6.40	745	2	13.5	3.5	47.3	0.21	9.9	9.2	0.11	0.44	5	30	40	20	5
S5.36	668	2	39.3	3.2	125.8	0.17	21.4	27.8	0.11	0.40	15	20	40	20	5
S3.43	545	2	10.7	4.8	51.4	0.14	7.2	11.6	0.23	0.23	10	35	35	20	0
S1.17	449	2	14.8	3.5	51.8	0.28	14.5	11.0	0.15	0.60	20	30	40	10	0
S8.91	927	3	9.8	2.8	27.4	0.42	11.5	15.6	0.00	0.60	40	25	20	15	0
S1.25	457	3	11.3	12.9	145.8	1.32	192.5	19.8	0.00	2.10	15	15	20	20	30
S4.1	586	3	15.3	8.8	134.6	0.52	70.0	24.6	0.00	1.30	40	30	20	10	0
S6.54	759	3	15.0	6.6	99.0	0.66	65.3	13.0	0.00	1.70	30	40	20	10	0
S7.25	823	3	4.8	3.3	15.8	0.55	8.7	13.1	0.00	0.83	60	20	10	10	0

Sample Code	No.	Unit	Length	Wet Width	Area	Depth	Volume	Channel Width	Vel.	Thalweg Depth	% Fine	% Sm Gravel	% Lg Gravel	% Cobble	% Boulder
S3.8	510	3	4.5	8.0	36.0	0.38	13.7	13.0	0.00	0.72	35	30	15	15	5
S6.39	744	4	25.0	4.8	120.0	0.42	50.4	9.5	0.00	0.82	20	30	30	15	5
S7.23	821	4	23.8	6.1	145.2	0.43	62.4	11.1	0.00	1.10	55	20	20	5	0
S3.20	522	4	22.3	9.0	200.7	0.35	70.2	13.2	0.00	0.90	30	20	25	15	10
S8.92	928	4	43.2	7.7	332.6	0.58	192.9	11.3	0.00	1.48	60	15	15	10	0
S9.1	946	4	24.0	6.3	151.2	0.44	66.5	7.1	0.00	0.68	20	20	40	20	0
S4.45	630	4	55.2	6.9	380.9	0.33	125.7	11.0	0.00	1.10	30	20	20	20	10

Sample Code	No.	Unit	Instr Log	Instr Boulder	Instr Veg	Overstr Veg	Cut Bank	Temp
C7.5	212	1	0.8	0.0	5.9	10.5	0.0	15.0
C8.114	429	1	0.0	0.7	8.0	0.7	0.0	15.0
C8.105	420	1	0.0	1.8	1.3	18.0	0.0	16.0
C8.61	376	1	5.6	0.2	3.5	19.9	0.0	15.0
C8.52	367	1	9.0	0.3	1.4	16.4	0.0	15.0
C7.104	311	1	2.0	6.3	2.5	1.5	2.4	16.0
C7.60	267	1	0.5	0.0	0.0	4.5	0.0	14.5
C7.53	260	1	0.5	0.0	0.3	3.0	0.0	14.0
C1.7	7	1	0.4	0.1	0.0	1.4	0.0	14.0
C4.72	125	1	0.2	17.8	0.0	9.0	0.0	12.5
C3.24	52	1	0.1	0.0	0.4	0.5	0.0	13.0
C4.53	106	1	0.2	0.6	0.8	1.0	0.0	12.0
C7.48	255	2	8.4	0.0	0.2	16.5	0.0	13.5
C8.56	371	2	0.6	0.6	3.9	12.5	0.0	15.0
C4.6	59	2	1.6	0.0	2.8	5.6	1.2	13.0
C8.35	350	2	1.2	0.0	0.2	4.0	1.2	14.5
C4.17	70	2	0.6	0.0	3.5	10.5	0.0	13.5
C5.34	169	2	8.8	0.0	6.0	14.0	7.1	12.0
C7.72	279	2	1.7	0.0	0.0	4.5	0.0	15.0
C8.99	414	2	8.5	0.5	1.7	15.0	7.9	16.0
C4.68	121	2	0.8	9.4	9.0	11.8	2.1	12.0
C7.6	213	2	0.1	0.0	9.5	21.5	0.0	15.0
C6.36	206	2	3.4	14.3	1.6	4.0	1.0	14.5
C2.4	12	2	0.3	1.0	0.5	0.8	0.0	13.0
C8.34	349	3	3.0	0.0	1.5	1.9	0.5	14.5
C6.15	185	3	2.7	0.0	0.0	12.2	0.6	14.5
C4.28	81	3	1.2	0.0	2.1	1.5	0.0	13.5
C2.10	18	3	0.3	0.0	8.0	33.0	0.0	13.0
C8.2	317	3	2.6	0.0	2.7	12.6	3.8	16.0
C7.63	270	3	2.6	0.0	0.0	1.4	3.2	15.0

Sample Code	No.	Unit	Instr Log	Instr Boulder	Instr Veg	Overstr Veg	Cut Bank	Temp
C8.106	421	4	3.5	1.0	2.4	8.5	3.1	16.0
C4.73	126	4	6.0	0.0	1.5	6.2	1.2	13.0
C8.101	416	4	8.0	1.5	8.5	54.5	0.0	16.5
C8.39	354	4	38.7	0.0	1.0	6.0	0.0	14.5
C7.18	225	4	6.3	0.0	13.6	25.0	0.0	15.0
C7.74	281	4	3.6	0.0	1.5	13.0	2.5	15.5
S5.1	633	1	0.4	23.4	5.5	4.0	0.0	17.0
S9.29	974	1	3.0	0.0	1.6	2.0	0.2	15.0
S8.85	921	1	0.0	0.0	2.7	0.5	0.0	16.0
S8.39	875	1	0.0	0.0	0.1	0.0	0.0	15.0
S7.19	817	1	3.3	0.3	0.6	11.0	0.0	16.0
S6.56	761	1	1.0	3.5	5.5	17.0	1.4	15.5
S6.30	735	1	0.2	0.7	0.0	5.0	0.0	15.0
S6.9	714	1	0.0	47.4	2.1	15.0	0.6	15.0
S5.7	639	1	0.0	0.0	3.3	1.0	0.0	17.0
S1.16	448	1	0.0	0.0	0.5	1.0	0.0	15.0
S2.31	488	1	2.1	0.0	0.0	2.0	0.0	14.0
S3.38	540	1	1.7	0.0	2.0	0.3	0.0	14.5
S4.35	620	2	26.1	0.0	9.2	19.0	1.0	16.5
S6.25	730	2	0.0	8.5	1.0	10.0	0.8	15.0
S9.14	959	2	0.0	0.0	6.1	1.0	0.0	16.0
S8.54	890	2	3.5	0.0	1.2	2.3	0.0	15.5
S8.11	847	2	0.9	0.0	0.8	9.5	3.5	15.0
S2.39	496	2	1.0	0.0	1.0	19.8	0.0	14.0
S7.13	811	2	0.0	0.0	3.2	3.5	0.0	16.0
S4.13	598	2	4.3	0.0	4.5	11.0	0.0	15.0
S6.40	745	2	4.0	0.9	4.2	5.0	0.0	15.5
S5.36	668	2	10.1	0.5	18.0	10.0	6.0	14.5
S3.43	545	2	0.0	0.0	4.0	16.0	0.0	14.5
S1.17	449	2	1.4	0.0	7.6	28.0	0.8	15.0
S8.91	927	3	1.0	0.0	2.9	2.0	4.8	16.0
S1.25	457	3	0.0	89.0	0.0	0.0	1.6	15.0
S4.1	586	3	126.0	0.0	3.0	2.0	0.0	14.0
S6.54	759	3	26.0	0.0	3.2	15.0	7.4	15.0
S7.25	823	3	1.0	0.0	0.0	5.0	0.0	16.0
S3.8	510	3	9.9	7.0	1.0	3.0	0.0	14.5
S6.39	744	4	1.0	7.2	8.4	7.0	1.2	15.5
S7.23	821	4	7.0	0.0	0.0	22.0	0.0	16.0
S3.20	522	4	4.3	46.8	0.5	31.0	0.0	14.5
S8.92	928	4	40.9	0.0	5.0	160.0	10.0	16.0
S9.1	946	4	3.2	0.0	2.0	14.0	23.7	16.0
S4.45	630	4	4.5	27.6	6.4	87.6	2.8	16.5

Appendix D

Comparison Between 1979-80 and 1989-90 Land Use Within a 500 m buffer of the Stream Network Above the Salmon River Gauge Station (#08MH090) at 72nd. Avenue.

Calculated for hectares (ha) and percent (%) of area.

Land Use Type	**1979-80**	**1989-90**	**% Change**
No Land Use Within Boundary	405 ha 12%	405 ha 12%	--
Agricultural	1789 ha 55%	1406 ha 44%	-11
Residential	93 ha 3%	229 ha 7%	+4
Undeveloped	764 ha 24%	946 ha 30%	+6
Commercial/Industrial	14 ha < 0.5%	39 ha 1%	+0.5
Extraction	4 ha < 0.5%	10 ha < 0.5%	--
Transportation/Utility	29 ha 1%	47 ha 2%	+1
Institutional	62 ha 2%	69 ha 2%	--
Recreational	68 ha 2%	77 ha 2%	--
Total	3228 ha	3228 ha	