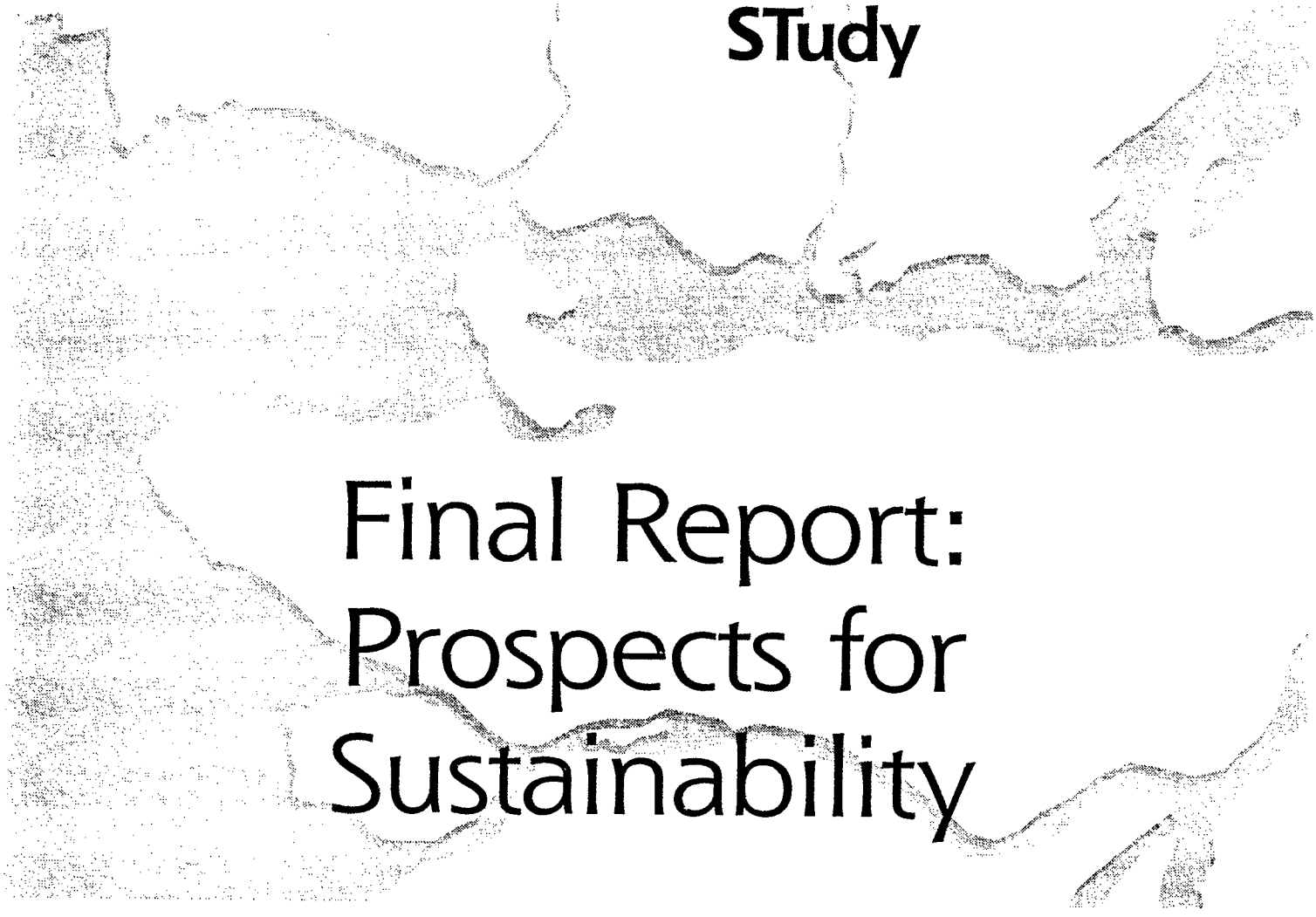
Fraser Basin Ecosystem STudy



Final Report: Prospects for Sustainability

THE UNIVERSITY OF BRITISH COLUMBIA

WESTWATER RESEARCH · CENTRE

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PROSPECTS FOR SUSTAINABILITY

INTEGRATIVE APPROACHES TO SUSTAINING THE ECOSYSTEM FUNCTION OF THE LOWER FRASER BASIN

FINAL REPORT ON THE TRI-COUNCIL FUNDED ECO-RESEARCH PROJECT AT UBC

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This report is derived from material collected by many faculty and students at UBC over a 4 year period of research on the ecosystem of the lower Fraser River basin and from discussions with these same individuals at meetings and workshops. Although I compiled and synthesized the material, I cannot claim ownership of either the information or the ideas. This was a collaborative project and anyone interested in the full authorship of this report should refer to the list of participants in the final section.

The research on which this report was based was supported by tax dollars provided under the federal Green Plan and administered by the Tri-Council Secretariat of the federal Granting Councils. Additional support was provided by Environment Canada, the Fraser River Estuary Management Program, the Greater Vancouver Regional District, the City of Richmond, the Township of Langley and the municipality of Abbotsford/Matsqui. *Please feel free to copy and distribute all or portions of the document. We only request that you acknowledge the source of any portions that are copied or reprinted.*

This is the second printing of our report. This edition is identical to the first except for minor corrections in spelling and addition of two reports by Dori Bixler to appendix 2 that were missed in the first printing.

Additional Information on the lower Fraser ecoresearch project is available on the Institute for Resources and Environment web site. Complete copies of the report may also be downloaded from the web site:
http://www.ire.ubc.ca/ecoresearch/

This printing will exhaust the funds available to print and distribute the report. We apologize to anyone who was unable to obtain a free copy. We hope that anyone interested in obtaining copies will be able to have the report photocopied or to download it from our web site.

M. Healey, UBC, November, 1997.

TABLE OF CONTENTS

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EXECUTIVE SUMMARY

The Problem of Sustainability in the Lower Fraser Ecosystem

This research project explored the prospects for sustainability in the settled portions of the lower Fraser River basin, an area of roughly 3090 km^2, extending from the town of Hope in the east to Vancouver in the west. This is a rapidly changing ecosystem. Population growth is nearly 2% per year. Ethnic character is in transition from predominantly European to predominantly Asian. Lifestyles are changing from rural to urban and the economy from resource based to service based. The region is rich in resources. The Fraser Valley contains productive farm lands while the River and its tributaries are important spawning and nursery grounds for salmon. Yet, the expanding metropolitan area threatens to overwhelm the natural resource base. The growing dominance of the urban environment means that the balance between local self-sufficiency and global inter-dependence is shifting rapidly towards grater dependence. At the same time, aboriginal peoples of the basin are demanding protection for their traditional ways. The lower Fraser basin, thus, exemplifies all the social, environmental and economic problems of modern industrial nations. Defining sustainable options for such a dynamic and complex ecosystem presents formidable challenges but such ecosystems are also at the core of the problem of sustainability.

The Eco-Research Project

Twenty-three faculty from 20 different departments, schools, institutions and centres at UBC and more than 40 graduate students participated in our 4 year study of prospects for sustainability in the lower Fraser. The research also involved collaboration with the federal, provincial, regional and municipal government agencies. The project was designed to build our institutional capacity to address complex, interdisciplinary problems relating to sustainable development, to resolve a range of technical problems of sustainable development in a rapidly changing ecosystem and to design policy options for sustainable development. We put together a multi-disciplinary research team and encouraged graduate students to undertake research that cut across traditional disciplines.

Our research was structured to address four fundamental questions related to sustainability: 1) What kind of an ecosystem do we have and how did it come to its present state; 2) What kind of an ecosystem do we want to have a generation from now; 3) What is feasible for us to accomplish; and 4) How (in terms of new policies and instruments) can we accomplish what we want? The results of our research highlighted the extent to which the lower Fraser basin has already been transformed by human activities and showed that present trends in population, economic development and land use are carrying us ever further from sustainable configurations.

Research Results

A little more than a century ago the lower Fraser basin was a forest of giant trees with extensive swamps and wetlands along the river courses. Now the valley is primarily farm and urban land and the farm land is being progressively absorbed by the growing metropolis of Greater Vancouver. These changes have resulted in considerable loss of ecological capability. The natural community was much more productive biologically than the farm and urban lands that have replaced it. The extent of the ecological transformation is illustrated by the regional plant community which, in the lowland areas of the valley, is now made up primarily of introduced species. Rapid human population growth and its changing ethnic composition are creating social tensions and straining the physical and social infrastructure of the community. As an ecosystem, the lower Fraser basin is sustained at present only through massive inputs of energy and materials. The ecological footprint of the basin is at least 25 times the land area of the valley.

The ecological transformations that we observe in the lower Fraser basin are driven primarily by market forces but are also encouraged by governments that see natural resources as a source of revenue and development as a source of power. Although the region is a desirable place for human habitation the stress of intensive human activity on the land, water and biota are becoming ever more evident. Urban streams are threatened by toxic substances in storm run-off from streets. Technology for controlling toxic storm run-off is generally not being implemented even in new construction. Intensive agriculture and improperly functioning septic systems are overloading valley soils with nutrients and other chemicals leading to contamination of aquifers and rural streams. The consequences are loss of desirable species, poor water quality and public health risks.

Analysis of community and regional plans reveals that residents of the lower Fraser are anxious to preserve rural landscapes and quality of life although there is a dichotomy between rural and urban communities in willingness to accept high rates of population growth. Polling of lower Fraser residents shows a high concern for maintaining environmental quality but also a belief that not much can be done to contain population growth and environmental change. Plans to manage growth aim at preserving an extensive and interconnected network of green spaces, creating compact and complete urban centres with a better balance between employment and population, and minimizing the need for extensive commuting. Unfortunately, powerful interests often work to undermine these plans. The choices that individuals make are important to achieving sustainable development. Paradoxically, individual choices often conflict with strongly stated beliefs and values, as in the stated concern of a majority of residents over air quality and automobile use at a time when individual automobile use is increasing dramatically.

The Need for Policy Reform

Changes in policies related to population, land and resources, consumption and waste management are needed if we are to move toward sustainability. What is feasible for us to achieve is constrained by a variety of factors such as the geography of the basin, the history of development and institutions to manage development, international trade and market forces, and the values and value systems of basin residents. An important unknown is the extent to which the emerging political power of aboriginal societies will affect patterns of development. Local decisions cannot bring our community to sustainability because much depends on decisions made elsewhere. Nevertheless, local decisions are critical to our future sustainability.

Tools for Policy Reform

To ensure that our research would be accessible to decision makers, we collaborated with government agencies in the study of a number of important local and regional problems such as non-point source pollution, urban stream rehabilitation, and the ecological impact of municipal by-laws. This allowed our results to have direct influence on decision making. The approach was particularly successful with municipal authorities for whom we were often able to provide timely information on immediate problems. We also developed and elaborated three broadly based policy analysis tools: the ecological footprint; the social caring capacity; and a computer based scenario analysis tool, QUEST. The ecological footprint is a tool for determining the land area needed to sustain the socio-economics of any defined community. Ecological footprint analysis shows clearly how dependent urbanizing regions like the lower Fraser are on extensive and unsecured land and resources distributed around the globe. The heuristic of the ecological footprint is being widely applied in a number of international analyses of sustainable development. Social caring capacity is a tool for examining the social impact of policies that reduce material consumption. This tool is still in its formative stages but shows promise as a means to identify policy prescriptions that reduce the ecological footprint of a community while increasing the quality of life. The computer model, QUEST, is a tool for defining and exploring future scenarios for the lower Fraser basin. Designed to allow decision makers to explore the interactions among policy choices and to highlight the trade-offs inherent in any attempt to change local socio-economic conditions, QUEST has generated a lot of interest locally and internationally.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations presented here all derive from our broadly based research on the lower Fraser basin ecosystem. We did not, however, attempt to come to consensus on all recommendations. It seems doubtful that we could have reached consensus on some recommendations given their controversial nature and the diversity of views within our team. Nor was full consensus necessarily desirable, as there are many workable configurations of sustainable development. The recommendations illustrate, therefore, the kinds of changes in policy and governance that will be needed if the lower Fraser basin, British Columbia, Canada and the world are to make progress toward sustainable development but they are not the only ways to achieve that end. Many of the more general recommendations will look familiar as similar proposals have been made in the past but not acted upon. This does not reduce their relevance. Rather, our research has emphasized the fact that the problem has not gone away and it is high time that we faced up to it. Some of the policies that we recommend already exist but have not been implemented. Again, we emphasize that sustainable development cannot be achieved with policy placebos. Real problems require real actions. Deciding to postpone action on sustainable development is the moral equivalent to deciding that we don't care about the health and prosperity of our grandchildren.

A Definition of Sustainability

We define sustainable development as development that is environmentally sustainable, economically viable and socially acceptable. By environmentally sustainable we mean that changes to the ecosystem do not degrade its biological productivity, biodiversity or regenerative capacity. By economically viable we mean that the human economy is capable of satisfying the reasonable material desires of the vast majority of its citizens. And by socially acceptable we mean that the vast majority of the population is willing to live in accordance with the rules of governance. Our analysis of the present state of the lower Fraser basin ecosystem shows that its present structure and the way it is changing are not environmentally sustainable. The ecosystem is being transformed into a configuration completely dominated by an urban metropolis, biological productivity is being diminished, biodiversity is lost and regenerative capacity degraded. The economy is doing well in terms of providing high material standards to the majority of residents but an increasing number of citizens are marginalized in the economy. This suggests that the viability of the economy, in terms of our definition of sustainable development, may be short lived. Social acceptability of the rules of governance may also be in jeopardy. Public apathy and cynicism toward the present systems of governance is widely reported and many communities and citizens are calling for more locally based decision making and more accountability of elected representatives. Rapid population growth and changing ethnicity are straining the bounds of social tolerance and contributing to dissatisfaction with present governance. Although these problems can be addressed without reference to sustainability, the growing need for policy changes raises the possibility of incorporating solutions that are more sustainable. Since all aspects of governance impinge on sustainability, all sectors of government must take responsibility for promoting and fostering sustainable development.

Recommendation 1:

All future policy reforms by all levels of government should have as a primary objective facilitating the transition to more sustainable forms of development.

Recommendation 2:

All levels of government should adopt sustainability as a primary mandate. This mandate should apply to all departments and institutions of government. No government department should be permitted to argue the sustainability is not its responsibility.

The Lower Fraser Basin in a Global Context

The ecosystem of the lower Fraser basin is intimately interconnected with and dependent on the larger global ecosystem. The present structure and function of the lower Fraser ecosystem can be maintained only by massive inputs of energy and materials from other regions of the globe. Furthermore, the waste products generated here can only be neutralized by ecological processes outside the basin. The ecological footprint of the basin, that is the total area of land and water needed to provide the raw materials and energy required to maintain the lifestyle of basin residents and to absorb their wastes, is at least 25 times the land area of the basin. Furthermore, the size of this ecological footprint grows daily as a consequence of our growing population, our growing individual material consumption and our continuing degradation of the absorptive and regenerative capability of the local ecosystem. The security of supply of the resources and energy needed to maintain our lifestyle and the ecological services needed to absorb our wastes is by no means assured. In fact, all communities of the globe are increasing their demands for materials, energy and ecological services so that competition for these resources is rising. Yet, the extent of our dependence on the global ecosystem and the impact of our actions on ecosystems elsewhere in the world is virtually invisible to us. The limits to growth in population, material and energy consumption are uncertain but this is no reason to brush aside their profound implications for our quality and security of life. All communities have a responsibility to identify and monitor their exchanges with the global ecosystem and to seek ways to increase the security of those exchanges that are critical to sustainable development. Tools that we developed, such as the ecological footprint analysis, social caring capacity analysis and the scenario analysis model, QUEST, can provide a framework for assessing these exchanges and for communicating their importance to local residents. Such measures of environmental and social impact need to become as familiar as measures of economic impact if we are to achieve sustainable development.

Recommendation 3:

Each community should monitor and routinely publicize measures of its dependence on material, energy and ecological services in the global commons and the means proposed to ensure the security of those services for the community or to reduce dependence on unsecured resources.

Implications for National Policy

Our research was primarily directed toward understanding how a regional ecosystem functions. However, we believe that the lower Fraser basin can serve as a model for other ecosystems that are being rapidly transformed by direct human activity. Furthermore, the division of powers between federal and provincial governments is such that the national government has significant responsibility for economic and social development and environmental management within our ecosystem. Many of the actions that might be taken locally to encourage sustainable development would be more effective if they were part of a national strategy. Although sustainable development is, ultimately, a global issue, the national government is the highest level that is fully accountable to Canadians. If Canada were to adopt a national strategy for sustainable development that properly recognized the interrelationship of environment, economy and society, it would have implications both inward to provincial and local decision making and outward to international decision making. Based on our research there are several areas in which the federal government could provide important leadership.

The federal government can provide leadership in the development and standardization of accounting systems for environmental and social well being in the context of sustainable development. These are needed to balance the use of indicators like GDP as measures of economic well being. Indeed, measures like GDP also need to be modified as they presently misrepresent the costs of resource liquidation as a benefit. Furthermore, the national government is in the best position to publicize these indicies in ways

that will allow citizens to make balanced decisions about trade-offs among economic, social and environmental benefits.

Recommendation 4:

The federal government should take the lead in developing and standardizing effective and meaningful indicators of environmental and social well being and in modifying economic indicators so that they do not misrepresent environmental and social costs as benefits.

The federal government can also provide leadership in the application of sustainability principles to decision making in all departments. In policy making, sustainability seems to be regarded as primarily an environmental issue whereas it is, in fact, an issue that pervades all aspects of governance. National leadership is not essential for other levels of government to adopt sustainability principals. Indeed, British Columbia has made progress in this regard through its round table on environment and economy and the commission on resources and environment. Nevertheless, national leadership would provide a great incentive for all provinces to adopt their own policies. And, it is only at the national level that sustainability principles can be worked into foreign policy.

Recommendation 5:

The federal government should incorporate sustainability principles and the mandate to promote sustainability into the decision making process for all departments. In particular, sustainability should be made a high priority for external affairs and should become a cornerstone of Canada's foreign policy. However, other areas of policy critical to sustainability, such as finance, immigration, transportation and trade, should also be built on the principals of sustainability.

It is traditional to think of Canada as a land of wide open spaces, sparsely populated and under developed. In fact, our ecological footprint analysis illustrates that on a global basis every square metre of land and water is already fully committed to either the direct or indirect sustenance of the present world population and its demands for energy and materials. Canada can provide leadership in recognizing this fact and in building the knowledge into national policy. For example, Canada is one of the few countries in the world without an ecological deficit in productive land. This does not mean that we have land to spare. Rather, it means that our open spaces provide critical ecological and resource services to the rest of the world. Protecting Canada's ecological capability and biodiversity should be made a matter of national priority as part of our contribution to global ecosystem health and sustainability but also as an issue of national environmental security.

Recommendation 6:

The federal government should adopt national policies on development and land use that recognize the critical importance of Canadian open spaces to global ecological health and well being.

Recommendation 7:

The federal government should adopt systems of taxation, tariffs and regulation (e.g. higher raw material and energy taxes, lower payroll and income taxes, tariffs adjusted to the material and energy content of goods and services, tradable pollution permits, full cost accounting) that will work to reduce material throughputs in society, increase economic efficiency and build stocks of natural capital.

The federal government can provide leadership in the application of sustainability principles to comprehensive land claims. Through land claims negotiations the federal government is pursuing fundamental changes in Canadian social policy and governance. In effect, a new order of government is being created that gives recognition to the inherent rights and title of aboriginal peoples. As a result of the

resolution of land claims, First Nations are likely to have an authority and responsibility for decisions affecting development that is out of proportion with their relatively small population. Devolution of authority is, therefore, an issue in sustainable development and the negotiations provide an important opportunity to frame the authority devolved to aboriginal governments in the context of sustainability principles. Given their attachment to place and the preservation of traditional lifestyles, aboriginal peoples should be receptive to the principals of sustainability and may be best positioned to design and implement policies based on sustainable development.

Recommendation 8:

In its comprehensive land claims negotiations, the federal government should seek to frame the devolution of authority to First Nations in the context of sustainability principles.

Rapid population growth and changing ethnic composition in the lower Fraser basin are contributing to a degree of social tension and strife that works against sustainability. There are a number of ways in which social policy should be adjusted to address these problems but most fall under provincial jurisdiction. One area in which the federal government has clear responsibility, however, is in immigration policy. Immigration policy is one facet of the broader issue of population policy which includes issues such as foreign aid, family planning, reproductive health services and child care. These tend to be emotionally charged issues and, therefore, difficult to address politically. Nor is Canada completely free to address these issues independent of international pressures. However, in the absence of an expressed population policy, Canada has a default policy that is made up of its fragmentary approach to various aspects of population. Furthermore, population is central to the problem of sustainability. The government cannot pursue sustainability and at the same time ignore population.

Recommendation 9:

The federal government should adopt a population policy for Canada that is consistent with the principles of sustainability. This policy should guide the formulation of related policies such as immigration, child care, health care and family planning.

Environmental pollution remains a problem that undermines progress toward sustainable development. Considerable progress has been made over the past few decades in control of the use and discharge of toxic substances in industry and in society as a whole. Our analysis of toxic substances in water and sediments of small watersheds, in moss and in resident fishes of the lower Fraser river shows that concentrations of most toxic substances have remained stable or gone down in recent years, although nutrients have gone up dramatically in agricultural areas. Toxic substances that have increased are primarily those associated with non-point sources of pollution, especially those associated with transportation. Whereas lead pollution has decreased with the removal of lead additives in gasoline, manganese has increased as manganese compounds have replaced lead as antiknock additives. Manganese is now receiving considerable attention as a possible health hazard but other trace metals associated with transportation (copper, zinc) should not be ignored.

Recommendation 10:

The federal government should take the lead in providing incentives to the transportation industry to design more ecologically friendly products and to adopt source control for toxic substances that will be released into the environment.

Implications for Provincial Policy

Just as it is important for the federal government so is it important for the provincial government to ensure that sustainability principles govern decision making in all departments. British Columbia has made

significant progress in recent years in recognizing the importance of a healthy and productive natural environment to the social and economic well being of the province. The integration of environment, economy and society that characterizes sustainable development has not been achieved, however, and this is no where more evident than in the lower Fraser basin. Attempts by Environment Lands and Parks to protect environmental values and preserve biodiversity in the lower Fraser will be futile if other ministries like Finance, Highways, and Agriculture don't consider overall sustainable development as part of their mandates. For example, the decision to widen the trans-Canada highway in short sections so as to avoid having to conduct an environmental impact assessment is a decision directly contrary to the principals of sustainable development.

Recommendation 11:

The provincial government should incorporate sustainability principles and the mandate to promote sustainability into the decision making process for all departments. No government department or agency should be in a position to argue that sustainability is not part of its responsibility.

In addition to making sustainability a mandate for all government departments, the provincial government also has an important role to play in developing and publicizing measures of sustainability. To be most effective, these should be consistent with any measures used by the federal government. The provincial government is also in the best position to encourage the practice of sustainable development principles in communities throughout the province. Communities that make progress toward sustainability should receive public recognition for their success whereas those that lose ground should also be recognized. Progress could be measured in a variety of ways including reductions in per-capita ecological footprint, reductions in material throughput, increases in recycling or increases in social capital.

Recommendation 12:

The provincial government should collaborate with the federal government in the development of indices or measures of progress toward sustainable development that are easily understood and meaningful to the public at large. The province should use these measures as a means to encourage more sustainable forms of development and to recognize publicly regional successes or failures in progress toward sustainability.

If the province is serious about sustainable development, it cannot avoid the issue of population any more than the federal government can. Population growth has become an issue of public concern in the lower Fraser basin because population is growing rapidly and this growth is straining the capacity of the regional infrastructure and causing rapid changes in the landscape and ethnicity. That population growth poses significant problems for environmental management and quality of life is implicit in regional plans, like the livable regions strategy. However, regional attempts to manage growth are handicapped by lack of complementary provincial policies.

Recommendation 13:

The provincial government should adopt a provincial policy on population consistent with principals of sustainability and as one of the foundations of provincial social policy for sustainable development.

Whereas issues like population are a shared responsibility of federal and provincial governments, resource use policy is almost entirely a provincial responsibility. Our analysis of the history of resource use within the lower Fraser basin has highlighted the fact that successive provincial governments have seen resources as a primary source of revenue. This coupled with a rather narrow focus on economic development has made the province an agent for the liquidation of natural capital rather than an agent for sustainable resource use. If environmental sustainability is to be achieved (i.e. no loss of biological productivity, biodiversity or regenerative capacity) then provincial policies must become more balanced in

their promotion of economy, environment and society. The remaining stock of natural capital must be sustained and increased over time if sustainable development is to be achieved.

Recommendation 14:

The provincial government should adopt policies that will generate revenue and reduce costs while encouraging increases in natural capital and quality of life rather than material consumption (e.g. shifting the tax burden from income and labour to material and energy use and from value added products to raw materials, encouraging local self-sufficiency and social networking as opposed to centralized government services).

Our research on small watersheds and non-point sources of pollution clearly demonstrated the importance of automobile traffic as a source of trace metal and hydrocarbon contaminants in urban streams. Although it was not part of our study, other investigations have implicated the automobile as the major source of air pollution within the lower Fraser basin. Transportation planning aims at reducing dependence on the private automobile but progress in implementing plans has been slow. Meanwhile, automobiles have been increasing faster than the population and kilometers driven even faster. Further delays in providing alternate forms of transportation and in discouraging automobile use means further declines in environmental quality, ecological capacity and public health. The provincial government has a significant role to play in managing emissions to protect ambient air, water and sediment quality and in construction and promotion of public transit and other, more environmentally friendly, forms of transportation.

Recommendation 15:

The provincial government should move speedily to adopt and implement a firm transportation policy that promotes environmentally friendly transportation and discourages further increases in automobile use. Elements of this policy should include routine emissions testing of all vehicles in the province, including commercial vehicles, financial support for an effective and efficient rapid transit system within the lower Fraser basin, financial incentives for commuters to use rapid transit, financial and other disincentives for the use of private automobiles as well as other measures to put transportation on a more environmentally and socially sustainable foundation.

Our research has confirmed that residents of the lower Fraser basin and BC residents in general believe that the limited farm lands in the province should be protected from development that would make the land unsuitable for farming. Our research has also shown that there is a continual alienation of farm lands from the land base in the lower Fraser as population grows and developers lobby for the removal of lands from the Agricultural Land Reserve. Furthermore, the intensification of agriculture in the lower Fraser means that much of the present agricultural production is decoupled from the land base. This is particularly the case with intensive poultry and hog production systems that import virtually all of their necessary feed. Overuse of the limited land base to dispose of agricultural wastes leads to contamination of streams and aquifers and our research also suggests that voluntary compliance with the code of waste management is poor. Several changes in provincial policy and regulations governing farming are suggested by our observations.

Recommendation 16:

The provincial government should adopt a no-net-loss of farm lands policy for BC. Where development proposals would alienate farm lands the developer should be required to show how farm lands elsewhere will be rehabilitated or enhanced so that no overall loss of farm potential occurs. Other measures, such as a provincial farm land bank might be created to protect farm lands. Farm land in the bank that is not presently being farmed could be used as park land, wildlife habitat or serve as an Ecological Service Centre.

Recommendation 17:

The provincial government should ensure speedy passage of legislation governing groundwater that enables government regulation and management of aquifer use and aquifer contamination. Guidelines and regulations governing land use in aquifer recharge areas should constitute part of the legislative package.

Recommendation 18:

The provincial government should make Best Management Practices (BMPs) for agricultural wastes (both commercial and hobby farms) and farm nutrient application a matter of regulation not voluntary guidelines. Each farm should have a nutrient budget appropriate to its operation and land base that will not lead to soil or water contamination.

Recommendation 19:

The province should implement a policy setting maximum animal stocking densities on farm land related to the capacity of soil types to absorb animal wastes. Densities should only be allowed to exceed these maximum densities where alternative forms of animal waste management are in place.

The pursuit of sustainable development is a new objective for our society and there is no established set of policies and programs by which sustainability can be achieved. Every attempt to move toward sustainable development is an experiment and there is no guarantee of success. Since various levels and orders of government have responsibility for aspects of sustainability, partnerships between governments will be required to ensure that real progress can be made. Since the public will be expected to pay the cost of our uncertain progress toward sustainability, the public must have meaningful involvement in the decision making process. Various planning processes within the lower Fraser basin region have provided a valuable framework for guiding decision making but, in many instances, plans have not been formally adopted or have been subverted by political agendas at a different level of government. The province has an important role to play in encouraging and fostering the necessary communication and consensus building among governments and the public at large.

Recommendation 20:

The province should adopt policies that specifically encourage the formation of partnerships among government agencies and levels of government to address provincial and regional issues in ways that integrate environmental, economic and social objectives. An important purpose of these partnerships should be to ensure consensus among governments and agencies in how issues will be addressed. This is particularly important for the inclusion of First Nations governments in regional decision making processes.

Recommendation 21:

The province should develop and implement an educational strategy specifically designed to acquaint the public with the meaning and principles of sustainable development. The strategy should target provincial bureaucrats, educational institutions, regional and municipal authorities, corporations and public interest groups. The strategy should be implemented coincidentally with the policy making sustainable development the mandate of all provincial agencies (Recommendation 11). The educational strategy should make use of compelling local examples such as the nutrient contamination in the Fraser Valley.

Recommendation 22:

The province should require that regional and community plans be updated on a regular basis (say every 5 years) with effective public consultation. Regional and municipal councils should also be required to adopt plans through formal votes in council.

Recommendation 23:

As sustainability principles begin to provide the framework for policy and administration in all government departments and begin to effect regional and municipal decision making, the provincial government should implement a system of public recognition for communities that show substantial improvements in provincial indices of sustainability and public identification of those that lose ground. This could be analogous to the list of 100 for polluters who exceed their permitted discharges.

Loss of biodiversity, species extinction, alien species invasion are all features of the ecological transformation of the lower Fraser basin. These changes show that ecosystem structure and function are not sustainable. The changes also progressively limit the options open to policy makers for sustainable configurations. Immediate steps need to be taken to protect critical habitats and landscapes so as not to foreclose attractive options for sustainable development.

Recommendation 24:

The provincial government should take immediate steps to preserve remaining areas of critical habitat in the lower Fraser basin, including the remaining wetlands and any remaining patches of native vegetation.

Implications for Regional and Municipal Policy

The Greater Vancouver Regional District (GVRD) has been very active in developing plans to cope with population growth and sustain environmental and quality of life values within its boundaries. Plans developed by the GVRD provide a basis for more sustainable forms of development within the region. Unfortunately, implementation of these plans has been slow and hampered by a variety of factors including bureaucratic resistance, municipal rivalries and opposition by vested interests. Furthermore, the GVRD plans do not apply to regional districts east of the GVRD. As these districts have recently been amalgamated into a single district (the Fraser Valley Regional District, FVRD) it is appropriate that a regional plan consistent with the principles of sustainable development be developed and adopted for the FVRD. A number of municipalities throughout the lower Fraser basin have also procrastinated about formally adopting official community plans.

Recommendation 25:

The GVRD should continue to promote implementation of the Livable Regions Strategy and its associated planning documents. Revisions to and updating of some of these plans are ongoing. The GVRD should ensure that such revisions are consistent with the principles of sustainable development.

Recommendation 26:

The FVRD should move quickly to develop and implement a regional plan complementary to the Livable Regions Strategy and consistent with the principles of sustainable development.

Recommendation 27:

Municipal governments that have not formally adopted official community plans or that have not reviewed their plan for more than 5 years should take steps to update and formally adopt plans that are consistent with sustainability principles.

Regional and municipal authorities have important roles to play in the development and implementation of local sustainable development policies. Our experience in working with municipalities has highlighted the enthusiasm and dedication that local citizens groups can bring to community based projects. Municipal and regional authorities are in the best position to help foster and mobilize this community enthusiasm and to encourage technical and other forms of support from provincial and federal governments. With modest assistance from municipal agencies, community groups can take on and administer a wide variety of projects that will help with the integration of environment, economy and society and provide important services to the community.

Recommendation 28:

Regional and municipal governments should provide modest organizational and technical support to community based groups that can take responsibility for projects to enhance community sustainability. Examples of projects that community groups could effectively undertake include delineating environmentally sensitive areas, monitoring aspects of environmental quality and environmental health, building social networks and social capital within the community, or promoting more environmentally sustainable forms of economic activity.

Recommendation 29:

Regional and municipal governments should promote the formation of partnerships among levels of government to address issues of sustainability. These partnerships provide an important mechanism for local communities to influence regulatory and management processes that are the primary responsibility of federal or provincial agencies. By means of such partnerships the community agenda can begin to drive the regulatory process.

The settlement of comprehensive land claims is expected to have a significant effect on resource and environmental management and development decisions within the lower Fraser basin. However, it will be some time before claims are settled and, in the interim, there is considerable uncertainty about the future. Regional and municipal authorities continue to make decisions about local development that impact on the aboriginal community and aboriginal authorities make decisions about reserve lands that raise concerns in the surrounding communities. Such fragmented and contradictory decision making is contrary to the principles of sustainable development and increases social tensions. Furthermore, there are many situations in which partnerships among local administrations would be highly mutually beneficial. A better process of communication is needed that will not jeopardize land claims but will help build trust and respect between aboriginal and non-aboriginal authorities.

Recommendation 30:

Aboriginal, regional district and municipal authorities should establish a consultative committee for the purpose of sharing information, ideas and community objectives and with a view to building trust, respect and partnerships between their respective administrations.

Small streams in the lower Fraser basin constitute a significant ecological resource that has historically been greatly undervalued. As many as 50 streams in the greater Vancouver area that once supported runs of Pacific salmon have been turned into storm sewers. Water and sediment quality in the remaining

streams are both degraded primarily as a result of non-point source pollution. In urban areas the most important sources of contamination are increasing automobile traffic and increasing amounts of impervious surfaces whereas in rural areas the most important sources are intensive agriculture, improper animal waste management and septic systems. Many municipalities have recognized the problems associated with non-point sources of pollution but little has been done to control the problem. In rural areas our research has shown that information and education programs have made farmers aware of the need for good waste management but have not convinced them to adopt the voluntary code of management. Several policy and regulatory changes at the regional district and municipal level are needed if non-point pollution is to be brought under control.

Recommendation 31:

Regional districts and municipalities should develop management frameworks and management plans for small watersheds to deal with non-point sources of pollution. The plans should include education programs to inform people about the connection between such activities as automobile use, farming and hobby farming, and septic systems and stream and groundwater contamination. The plans should also include a monitoring program that takes account of the highly variable conditions caused by storm water run-off. These management plans should be developed in consultation with all relevant interests and should involve a component of public stewardship and watershed restoration.

Recommendation 32:

Best Management Practices (BMPs) for waste management and control of run-off from land should be implemented. In urban areas, technology and BMPs to minimize impervious surfaces and control sediment and hydrocarbon transportation into streams should be required in all new developments. As municipalities upgrade or modify existing storm sewers, these should be brought up to standard in terms of technology and BMPs to minimized contaminant transfer to streams. In rural areas proper technology and BMPs for farm waste management should be a matter of regulation not voluntary compliance. Hobby farmers should also be required to manage their farm wastes appropriately. Households on septic systems should be required to service their system at regular intervals.

Recommendation 33:

Guidelines for residential and agricultural development over sensitive aquifers that will prevent contamination of the aquifer should be developed. Where development over aquifers is already leading to contamination, programs to reduce the contaminant loading and restore the aquifer should be implemented.

Our experience working with local communities has also shown how valuable the linkages between the university and the community can be in enhancing the exchange of information and ideas and in providing support for community based initiatives. The university benefits greatly from such a partnership by demonstrating that it has value and is relevant to the community. Graduate students gain important practical experience in real world problems and in working in non-academic settings. The community based activity promoted by the eco-research program is not a routine aspect of university life but is one that all public higher educational institutions should take seriously.

Recommendation 34:

Provincial and regional public institutions of higher education should have, as a formal part of their mandate, the requirement to provide technical and information back up to local communities to assist with local and regional problems.

Recommendation 35:

Funds should be provided by the province to support university/community collaborations with a requirement for some matching of resources by communities that receive funds or participate in projects. The funds should be administered by a regionally based committee and distributed on a competitive basis. The objectives of the fund should be to assist communities with real local problems and to encourage university faculty and students who are prepared to work with local communities.

Implications for Individual Decision Making

Policy development and policy reform at various levels of government are important to sustainable development. In the final analysis, however, whether or not we will achieve sustainable development in our society depends on individual decisions such as where to live, what kind of life-style to lead, who to vote for, and what kinds of community activities to support. While it is convenient to point the finger at governments and corporations for failing to deliver on sustainability, if our environment is degraded, if the economy fails to provide for our basic needs, if our society is balkanized and filled with conflict, it is we who must accept responsibility. The results of our poling indicate a high level of concern among the public for environmental and quality of life values and a willingness to make sacrifices to ensure that these values are sustained. Yet, individual behaviour often runs contrary to people's stated beliefs. In part this is because the system of infrastructure we have built up over time was predicated on human activities that are not sustainable. This infrastructure encourages us to continue, in an almost unconscious way, with activities that are unsustainable and that are in conflict with our present values. Individuals need to reassess their values and their individual decisions and begin to make conscious choices that more closely reflect the values they espouse. We offer a number of recommendations that we hope will stimulate some debate, both public and private, about the role of individuals in sustainable development.

For Your Environment:

Recommendation 36:

Take responsibility for your own excessive consumption of material and resources. Assess your individual ecological footprint and develop a program to reduce your footprint by some measurable but achievable amount. Make footprint reduction a family game. Organize a community group to explore ways to reduce the footprint of your community.

Recommendation 37:

Learn about the environmental implications of the things that are going on in your community. Don't support those that will increase your individual contribution to environmental degradation or that will affect the quality of your environment. Get involved with those things that will increase environmental quality or rehabilitate the environment.

Recommendation 38:

Learn about the environmental policies and beliefs of the political parties and the individuals who run for office in your community (regardless of the level or type of office). Don't support those that are contrary to your personal values about the environment or that do not put high priority on sustaining environmental quality.

For Your Community

Recommendation 39:

Act to overcome evident social divisions in your community. Question the balance of representation in council chambers, business and service organizations.

Recommendation 40:

Take responsibility for your role in the social cohesiveness of your community. Look for ways to increase the quality of your life and the lives of others through social networking. Look for ways to increase community and individual security by building social relationships.

Recommendation 41:

Remind your council members and other community leaders of their responsibility to base their decisions on sustainability principles. Participate in activities that help your community to be a voice for sustainable development in regional, provincial and national affairs.

For Your Economy

Recommendation 42:

Learn to distinguish between economic proposals that enhance sustainability in your community and those that enrich a small number at the expense of the community. Support the former and oppose the latter.

Recommendation 43:

Make charts of how you dispose of personal or family income. Consider how different patterns of income allocation might support locally beneficial economic activities without reducing your quality of life.

Recommendation 44:

Use your purchasing power to support environmentally and socially friendly products and manufacturing processes. Make buying sustainably a family game. Start or join a local consumer group with similar objectives.

It is worth re-emphasizing that there is no single pattern of sustainable development and no single way to move toward sustainable development. The principles of sustainable development provide a framework within which there is considerable opportunity for individual creativity. We hope that the residents of the lower Fraser basin and the people of Canada will rise to the challenge and the opportunity of sustainability. The alternative does not appear very attractive in the long term.

CONTEXT

The Ecosystem of the Lower Fraser River Basin:

The geographic focus of UBC's eco-research project was the floodplain ecosystem and adjacent uplands of the lower Fraser River basin. In biophysical terms the region may be defined as the Fraser Lowland Ecosection, a subdivision of the Lower Mainland Ecoregion. The Fraser Lowland is the valley floor below an elevation of 150 m, which was roughly the zone of marine inundation before the land rebounded following the last glaciation. It occupies about 4000 km^2 of which about 3090 km^2 are within Canada. The Fraser Lowland is a narrow triangle with its apex at the town of Hope and gradually widening to a base approximately 40 km wide at the river mouth 160 km to the west. The triangle of lowland is sharply bounded to the north and south by steep mountain slopes that rise to elevations of 1500-2000 m and to the west by the Strait of Georgia. It is a rare area of gentle lowland in an otherwise rugged and precipitous coastline.

For the past 10,000 years, as the glaciers and the sea receded from the valley, the Fraser River has defined and shaped this ecosystem. The Fraser is one of the largest rivers in the Pacific Northwest, draining a catchment of approximately 234,000 km^2 and flowing approximately 1200 km before entering the Fraser Lowland. Nowadays, the River generally hugs the northern margin of the valley. In the past, it has followed different paths, dissecting and reshaping the valley floor into a mosaic of marine and fluvial sediments.

At Hope, the average discharge of the Fraser River is 2730 m^3/s. Downstream, the river is joined by several substantial tributaries, particularly from the north, so that at its mouth, the discharge is about 3700 m^3/s. The Fraser River is primarily fed by melting snow and glaciers in the interior of the province. It experiences its greatest flow (as high as 14,000 m^3/s) during the peak of snow-melt from late May until early July and its lowest flow (as low as 500 m^3/s) in late winter. The tributaries of the lower Fraser, however, are fed by a combination of melting snow and rain, so that they typically experience their flood flows in winter and are much more variable in flow. The river and its tributaries provide spawning and nursery habitat to five species of Pacific salmon, steelhead and cutthroat trout as well as white sturgeon, eulachon and approximately 30 other species of fishes.

During periods of peak flow, if unimpeded, the river and its tributaries would typically over-top their banks and invade the adjacent land. The seasonal flooding and the low relief of lands adjacent to the river meant that, when European colonists arrived about 200 years ago, the river margin was a complex of swamps and wetlands that occupied about 1000 km^2. These wetland habitats were dominated by sedge and cattail meadows in the wettest regions grading to willow, hardhack, wild crab apple and pin cherry in dryer areas and finally to cottonwood and cedar. At higher elevations were dense forests of western hemlock and Douglas fir.

The lower Fraser ecosystem has been inhabited for at least 9000 years by coast Salish peoples and their ancestors. Although the local population swelled in the summer and early fall as outlying villages congregated in the lower Fraser to take advantage of the seasonal salmon runs, the population was never more than a few tens of thousands prior to European colonization. The technological capability of the aboriginal inhabitants to exploit and modify the land- and water-scapes of the Fraser lowland was limited and the impact of aboriginal civilization on the ecosystem was relatively small.

During the past 200 years of colonization, however, the ecosystem of the lower Fraser has been dramatically transformed. The forest cover has been stripped away and the rivers diked to prevent flooding of the marginal lands. Only a remnant of the former forest cover remains and much of that is managed to provide fiber for wood products. The wood products industry is the core of the provincial economy and much of it is located in the lower Fraser. However, the wood that the mills process is now

almost entirely imported from elsewhere in the province. The extensive wetlands have been drained and converted to farmland. The lower Fraser contains the richest farmland in the province. Although it has only 2.8% of the arable land in the province it produces 50% of the agricultural value. The population of the region presently stands at 1.8 million and has been growing at about 2% per year for about the last two decades. The lower Fraser is one of the most rapidly expanding urban communities in Canada. It is also going through an ethnic transition. During 1995, for the first time, the population was dominated by individuals who's first language was not English. These rapid demographic changes are contributing to social uncertainty and ethnic strife.

The region is also in the midst of an economic transition. Although resource based industries still dominate, service and financial industries are growing in strength. The lower 80 km of the river provides important harbour facilities for international shipping, storage and transportation of logs for local sawmilling, and waste dilution for industrial and domestic wastes. The growing city has enveloped the industrial and transportation facilities along the river and around adjacent Burrard Inlet and is expanding eastward up the valley. The expanding urban metropolis of greater Vancouver is taking on the role of financial and service centre for Canada's growing trade with Asia. It is also threatening to overwhelm the small rural communities in the eastern part of the valley raising concerns about conservation of green space, amenity values and rural ways of life. The growing dominance of the urban environment in the lower Fraser basin also means that the balance between local self-sufficiency and global inter-dependence is shifting rapidly. In ecological and environmental terms, the lower Fraser basin cannot be considered in isolation from the global ecosystem.

The aboriginal peoples of the valley have been politically marginalized throughout the environmental, social and economic transitions that accompanied colonization. They are no longer willing to accept that subordinate role and are negotiating aggressively for a new place in Canadian society that recognizes their historic rights. What role aboriginal societies will play in the future of the lower Fraser basin is unclear and this contributes to the uncertainty and complexity of questions concerning integration of environment, economy and society.

The lower Fraser River basin, thus, exemplifies all of the major environmental and economic conflicts that characterize modern industrial nations. An understanding of the prospects for sustainability in the Fraser Lowland ecosystem has implications for sustainability in a global context. The Fraser Lowland is also the most significant region of the province in economic and social terms. The prospects for sustainability of the lower Fraser basin define the prospects for sustainability in the province as a whole. By addressing the sustainability of the lower Fraser, therefore, our research provides insights not only into the resolution of local problems but a model for sustainable environmental management nationally and internationally.

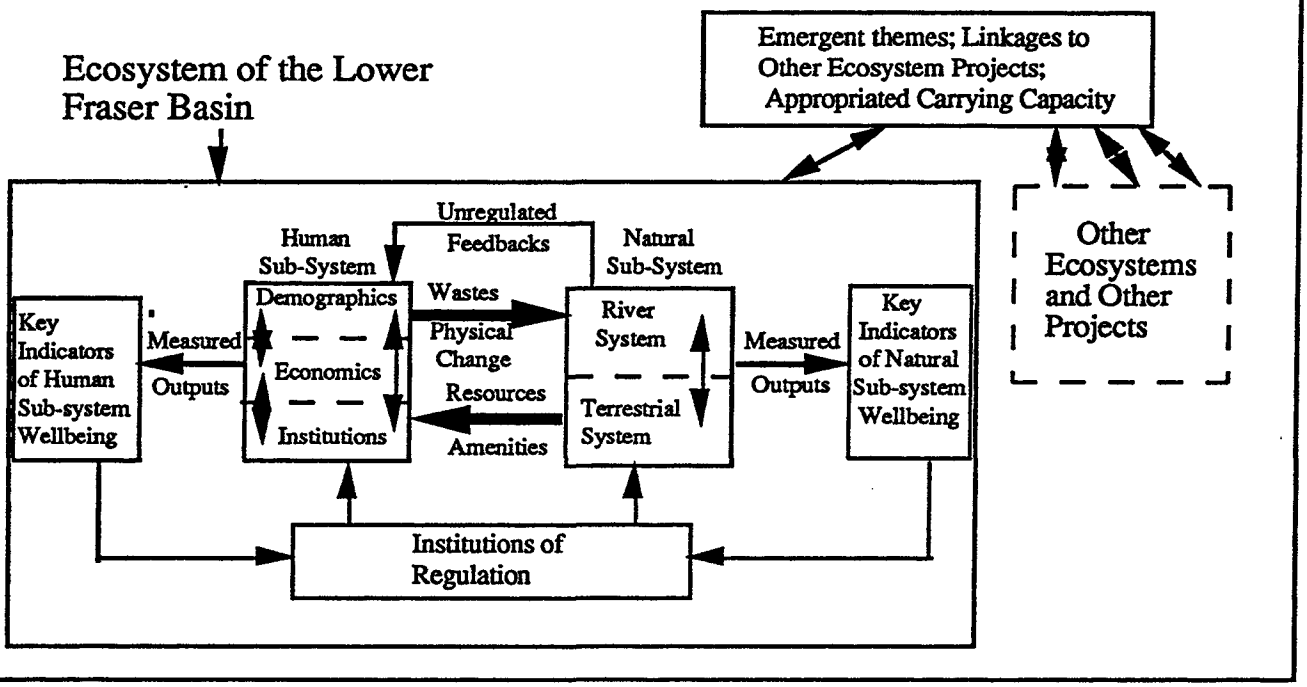
The Research Program

UBC's Eco-research program had three broad objectives in keeping with the reasons for which funding was provided through the Green Plan: scientific objectives, institutional objectives and policy objectives. The scientific objective was to conduct research that addressed four fundamental questions about sustainable environmental management. These questions and the research on them will be elaborated in detail in the section on research results. Here we would like to emphasize that our research involved integrating information and analyses across a range of disciplines in a holistic ecosystem-based approach. The system based structure of the research is illustrated in Figure 1.

Important attributes of this representation of the ecosystem are the strong interactions between the human and natural sub-systems, and the presence of both regulated and unregulated feed back processes that drive system evolution. The key indicators of human and natural subsystem health are the variables that we measured to assess both the current state of the system and its response to any proposed new policy or institutional instrument. The diagram also recognizes that the lower Fraser basin has both intrinsic value

FIGURE 1

THE LOWER FRASER RIVER BASIN ECO-RESEARCH PROJECT



to those of us who live here and extrinsic value as a model for sustainable management of other ecosystems.

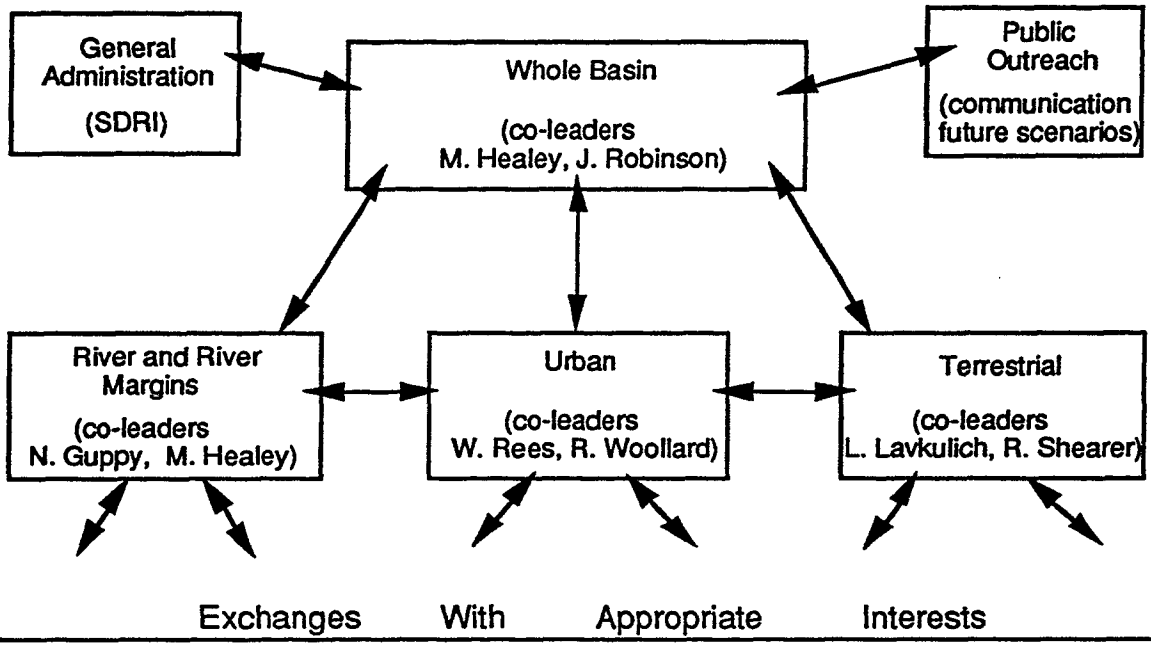
Our project was not intended to develop a comprehensive model of the Fraser Lowland ecosystem. However, we did aim for a coherent vision of ecosystem structure and function so that we could discuss the integration of environment, economy and society at various levels. We were aided in this by the fact that ours was not the only research being undertaken in the Fraser Basin. In particular, the federal Departments of Environment and Fisheries and Oceans were conducting a wide range of environmental research under the Fraser River Action Plan. Our research benefited considerably from close linkages and associations with this research and through professional relationships with researchers in federal and provincial agencies and the Fraser River Estuary Management Program. Our research on non-point sources of pollution received additional financial support from the Department of Environment and our development of QUEST, the computer based game for exploring future scenarios also received additional support from the Greater Vancouver Regional District.

Our institutional objective was to create interdisciplinary research capability at UBC that would foster the integration of information and expertise among natural, social and medical sciences and provide training for students in interdisciplinary research. At the time of the grant application, UBC had a number of interdisciplinary research centres and institutions (e.g. The Westwater Research Centre, The Sustainable Development Research Institute, The Resource Management and Environmental Studies Program). The Lower Fraser Basin project brought these three institutions together as well as faculty and students from a number of other disciplinary departments in a collaborative program of research and graduate education that provided a rich intellectual environment for interdisciplinary exchange and education. During the tenure of the grant, the Westwater Research Centre and the Resource Management and Environmental Studies Program were amalgamated into a new Institute for Resources and Environment. This amalgamation combined a strong research unit with a strong interdisciplinary graduate program to create a

new Institution well suited to carry on the role and tradition of interdisciplinary environmental research and education at UBC.

Once the final program structure was decided, 23 faculty were actively involved in the research project. Taking account of the disciplinary cross-appointments of the faculty in Westwater Research, Resource Management and Environmental Studies and Sustainable Development Research Institute, these faculty represented the departments of economics, anthropology and sociology, social work, business administration, family practice, soil science, civil engineering, botany, oceanography, bio-resource engineering, political science, health care and epidemiology, nursing, health promotion research, and geography and the school of community and regional planning. Research projects were organized into three geographical subdivisions of the lower Fraser (The river and river margins sub-system, the urban sub-system and the rural terrestrial sub-system) and a whole basin component with responsibility for integrating results from the three sub-system components. The administrative organization is shown in Figure 2.

FIGURE 2
ADMINISTRATIVE ORGANIZATION OF UBC'S ECO-RESEARCH PROGRAM



The administrative organization was intended to facilitate exchange of information and integration of information among disciplines and with relevant interest groups within the community. Each component of the project was co-led by a natural and a social scientist. The component leaders were the core of a whole basin committee who's job it was to ensure communication among components and to address issues of integration across projects and disciplines.

Graduate students conducted their research within the various sub-components of the project but were also involved in discussions and workshops that were intended to draw together the broad range of information being gathered.

Communication with outside interests in government agencies or the communities of the lower Fraser basin was conducted as a part of each sub-component. By this means the researchers were brought into direct contact with community members and potential users of their results and outside interests had opportunity to influence the direction of research results in a direct manner.

RESEARCH RESULTS

Introduction

Canada embraced the concept of sustainable development as articulated in the report of the World Commission on Environment and Development in the late 1980's. An over-arching goal of sustainable development is to create patterns of resource use that satisfy the current needs of society without jeopardizing the ability of future generations to meet their needs. One example of the Federal commitment to sustainable development was the creation of the Green Plan, a framework for moving the Canadian society and economy toward sustainable development. At the time that the Green Plan was announced, there was no general agreement as to the policies and institutions that were necessary to achieve sustainability and no well established bench-marks against which to judge progress. The Green Plan, therefore, provided support for a number of studies that would help establish the necessary policies, institutional arrangements and bench-marks. Several of the studies were cross-disciplinary investigations of regional ecosystems with the objective of integrating natural, social and medical sciences in the analysis of institutional options and policies for sustainable development. The UBC based study, "Prospects for Sustainability in the Lower Fraser River Basin", was one of these.

In fleshing out the concept of sustainable development, many economists and ecologists have come to agree that the conservation of some minimal quantity of certain natural resources and ecosystem processes is an essential prerequisite to sustainability. Some forms of such "natural capital" assets perform vital life-support functions, their loss would be irreversible and there are no technological substitutes. Other forms sustain economic activities that society regards as intrinsically valuable (fishing, farming and forestry for example). Still others provide amenity and quality of life values that are not well captured in the market-place. In practical terms, it is a necessary condition of sustainable development that each generation pass on to the next at least an adequate stock of essential natural capital. An important aspect of sustainable development, therefore, is having an inventory of natural capital assets and their quality. Defining these assets, determining how they are distributed and how human activities affect them was an important aspect of our research.

Humankind has become an important and dominant species in all the world's major ecosystems. Human economic activity is now capable of disrupting vital biophysical processes worldwide. In our research, therefore, we took the view that the human economy is a fully (if somewhat disfunctionally) integrated component of the natural environment. By taking this view we assumed that the economy is dependent on the ecosphere and our continued economic well-being is ultimately tied to our stewardship of the ecosystem. This means that, if we are to achieve sustainable development, the maintenance of natural assets must take priority over economic expansion in many development decisions. Our analysis of institutional and policy options for sustainability was intended to reveal how this critical environment-economy trade-off was to be handled if sustainability was the goal.

Maintenance of environmental capacity to sustain human economic and social arrangements is at the core of sustainability. None of the traditional academic disciplines encompasses the breadth of information and models needed to do this. Information exchange and integration across disciplines is needed. An important objective of our research was to seek such integration among institutional, scientific, and technological approaches to sustaining ecosystem function in the lower Fraser basin. To do this, we had to integrate social, natural and medical sciences within a collaborative program of research, experimentation, public consultation, and policy analysis. Establishing research priorities and maintaining direction over such a range of disciplines can be a potentially overwhelming task. We needed a framework that would both guide the research and help with the integration among disciplines and areas of research. The framework that we used took the form of four fundamental and policy relevant research questions. These questions linked the various research projects and the components of the study by relating each aspect of the research to the sustainability of the whole ecosystem and by defining a logical sequence of linkages between natural sciences, social sciences, medical sciences and policy development.

The four fundamental questions were:

1. What kind of an ecosystem do we have and how did it come to its present state;
2. What kind of an ecosystem do we want to have a generation from now;
3. What is feasible for us to accomplish; and
4. How (in terms of new policies and instruments) can we accomplish what we want?

These four questions not only provided a framework for our research, they are at the heart of any realistic program to manage the environment of the region in a sustainable manner. As will become clear below, in attempting to answer these questions we were forced to address many uncomfortable trade-offs between economic growth, environmental quality and social caring. They also brought us face to face with important contradictions between what we say we want and what we actually do. These contradictions constitute important impediments to achieving a sustainable relationship with the environment. One important objective of this final report is to highlight the trade-offs and contradictions that our research suggests are slowing our progress toward sustainable development.

For practical purposes the research was organized into four components: the whole basin; the river and river margins; sustainable urban systems; and rural terrestrial systems. The latter three components represent somewhat artificial subdivisions of the geography of the basin. To a degree, the urban and rural terrestrial sub-components capture the two major patterns of land use in the basin while the river and river margins sub-component identifies an important integrating and connecting ecosystem. The intent of the whole basin sub-component was to bridge the artificial subdivision represented by the other sub-components and pull the various threads of research into a coherent whole. Our research was also conducted at several geographical and conceptual scales so that we are able to assess prospects for sustainability from local, regional and global perspectives. For example, within the River and River Margins component a broad scale study was made of the whole Fraser River ecosystem and more detailed studies of several smaller tributaries that represented various degrees of human alteration of the environment (Figure 3). The analyses of economic history, demography and ecological footprint took on the basin as a whole whereas analyses of social movements, community health and sustainable urban systems centred on the communities of Richmond and Abbotsford (Figure 3). The various studies contribute to a vision of how the environment, economy and society of the valley could be made more sustainable. In this report the results of our research are synthesized so as to articulate this vision. The synthesis is organized in the context of our four fundamental questions.

What kind of an ecosystem do we have and how did it come to its present state?

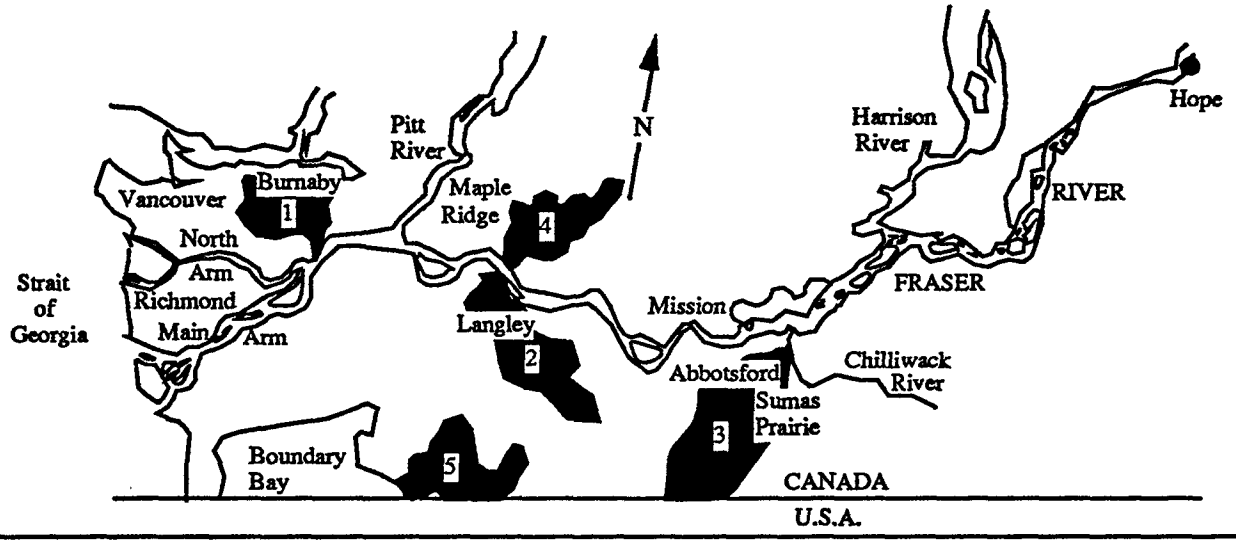
Introduction:

Our analysis of the ecosystem of the lower Fraser River has included considerable emphasis on what the basin was like in the past and how it came to its present condition. This emphasis on history was based in the belief that understanding the history of the basin would both give context to the present and provide insights into how we might plan to influence the future. In fact, the economic, environmental and social transformation of the lower Fraser ecosystem over the past 200 years has been so dramatic it is hard to imagine that any future transformation could be greater in extent or impact. Present day social, economic and environmental institutions are a legacy of the past. It seems reasonable that if we can understand the forces that shaped the institutions we, have we will be better equipped to adapt those institutions or invent new institutions for sustainable development. We undertook fairly detailed analyses of the economic and environmental histories of the basin with lesser emphasis on the more recent demographic history.

Our analysis of the present state of the ecosystem addressed a number of critical issues relating to the environment and social aspects of sustainability. Under environment we addressed issues of non-point sources of pollution, dynamics and cycling of nitrogen and carbon in the system, plant biodiversity, and fish diversity and health as indicators of overall ecosystem health. Under society we addressed the changing demographic character of the basin, how attitudes toward environment and economy are influenced by demographics, and how present day institutional arrangements influence the management

of water quality. We did not undertake any direct analysis of the present day economy of the basin as this has been well covered in a number of recent publications. Instead we assessed the interaction of environment, economy and society through an analysis of the ecological footprint of the lower Fraser basin. The ecological footprint refers to the total land base required to sustain present patterns of socio-economic activity in the basin.

FIGURE 3
MAP OF THE LOWER FRASER SHOWING LANDMARKS, SMALL WATERSHEDS (1 = Brunette, 2 = Salmon, 3 = Sumas, 4 = Kanaka, 5 = Little Campbell) AND COMMUNITIES THAT WERE THE SUBJECT OF PARTICULAR STUDY (Richmond, Langley, Abbotsford)



History of Environment, Economy, Society Interactions

Prior to 1800 the ecosystem was a landscape of dense forests, river channels and extensive fresh and salt water marshes. It was inhabited by a modest number of native Canadians who had sustained their hunter-gatherer economy on the local resources for about 9000 years. European colonization changed the economy and the local resource base rapidly and dramatically. In the course of a mere 200 years the valley was cleared of trees, farmsteads were established, and a growing metropolis is now taking over the land base. It is instructive to ask what were the forces that drove this rapid transformation of the ecosystem, what roles did government policy play, and was environmental conservation an issue?

Our research suggests that economic forces were paramount in driving the ecological transformations of the lower Fraser ecosystem. Three points should be emphasized about the way the economy developed in the lower Fraser basin following European colonization. First, the basin was richly endowed with marketable natural resources. Not surprisingly, therefore, the economy developed first as a resource extraction and processing economy. Second, the resources in greatest abundance (trees, fish, soils) were renewable. In theory, therefore, a resource based economy that could be sustained for centuries was possible. Indeed, such an economy had sustained the aboriginal society for thousands of years prior to colonization. Third, under the pressure of economic activity, the economically relevant elements of the environment changed over time. The forests disappeared, to be replaced in part by agricultural land. The dominance of the forest related industries declined, to be replaced by a more complex mixture of resource based industries, secondary manufacturing and services. The metropolitan area expanded, creating a demand for land for housing and industrial development, and absorbing large amounts of former forest/agricultural lands. Thus, there was a dynamic interaction between the environment and the

economy. The environment encouraged certain kinds of economic activity, which changed the environment and altered the kind of economic activity that was viable. This process continues to the present day.

The lower Fraser basin is not unique in this regard. It is an example of a process of economic-environment interaction that has and is occurring throughout the world. But this observation raises important questions for sustainability. Why does the economy alter the environment? If the resources that sustain the economy are renewable, why do such major environmental transformations occur? Why are renewable resources mined or abandoned in favour of other kinds of activity? Such mutually destructive environment/economy interactions are clearly not a necessary outcome of human activity, as the long lasting aboriginal economy illustrates. They do, however, appear to be a feature of post-industrial economies. The causes appear to lie in the motivation of governments and business firms and the institutions that govern the interactions among the environment, the economy and society.

Although globalization of the lower Fraser economy began with the fur trade, for various reasons this economic activity had relatively little impact on either the resource base or the social structures of the local inhabitants. It was the gold rush of 1857-58 that truly initiated the transformation of the economy and environment of the basin. Immigrants began to arrive in numbers, institutions and concepts of British society were substituted for those of the original inhabitants, and aboriginal peoples were marginalized in an economic system they could no longer control. Confederation between British Columbia and Canada in 1871 confirmed crown ownership of the economically relevant elements of the natural environment with the right of ownership divided between the federal and provincial heads of power.

Both federal and provincial governments sold or leased rights to vast areas of land and natural resources to individuals and businesses. In some cases the rights were limited to the harvesting of a particular resource within a finite period and the government, as landlord, reserved the right to set the rules of harvesting. In other cases rights transferred to private interests were comprehensive, involving ownership of both surface and sub-surface resources. Most of the fertile valley bottom lands were transferred to private ownership in this way. Nevertheless, both levels of government retained broad powers over both the economy and the environment. Transformation of the lower Fraser ecosystem was, therefore, both a consequence of the transfer of resources to private hands and the establishment, by both levels of government, of an institutional framework conducive to natural resource exploitation.

A government's thirst for revenues will virtually guarantee that it will regard any resources that it owns as a source of revenue. Initially, the government of BC attempted to generate revenue through the sale of land but the results were disappointing. Land disposal became more a tool for fostering settlement than for generating revenue. While BC was a separate colony it was able to generate revenue through customs tariffs but this source of funds was lost to the federal government following confederation. Initially, subsidies from the federal government made the financial situation of the province relatively comfortable. Government expenditures accelerated after the coming of the railway, however, and especially during an intense international economic boom in the late 1890's. For additional revenue the government turned to its timber resources so as to capitalize on the expanding market for timber during the boom.

Fees for harvesting timber on crown land were increased and timber harvesting rights were offered on favourable terms. As accessible standing timber had already been depleted in many other parts of the continent, considerable capital was attracted to the province and provincial revenues increased. The intent of forestry policy was to generate short term revenue, not conserve resources. Implicit and explicit incentives were created to harvest trees quickly. The annual fee for a forest harvest lease or license could be avoided by harvesting quickly and returning the land to the government. Under an 1877 law, a timber license could be canceled if the licensee did not cut an adequate volume of wood. In 1899 a minimum royalty was established per acre of land whether timber was harvested or not, explicitly to encourage harvesting. A similar "wild-land" tax on private forest lands was intended to induce private owners to harvest the trees or turn the forest over to the government for reassignment.

A second imperative of government decision making, co-equal with and complementary to the imperative to secure revenues, is the imperative to "develop" a region. From social and political perspectives, development has the twin attractions that it creates the impression of prosperity and a local increase in power and prestige. As a consequence, successive governments defined "development" as a regional priority. Initially this meant the creation of an outpost of British civilization by encouraging settlement and clearing land for farms and other kinds of local resource production. In the early stages, industrialization of the lower Fraser involved the primary processing of local resources, particularly the establishment of sawmills and shingle mills, but also fish canneries and creameries.

The conversion of the valley bottom from forests, swamps and flood plains to agriculture, industry and housing is an example of a radical environmental change that was deliberate. Although the conversion was undertaken mainly by private individuals and businesses, the government intended it to happen and provided strong encouragement. Land, including rights to the timber on it, were transferred to individual settlers. The government provided information and technical advice on farming. Roads, bridges and a railway were built. Despite these measures, however, the pace of settlement and development of agriculture were disappointingly slow. Intermittent flooding of river margin lands discouraged settlement on the river bank whereas clearing of dense forests on the dryer sites required inputs of capital and labour not available to most settlers.

The construction of three railways connecting the forested areas south of the river with the mills, markets and ports of the metropolitan area finally permitted intensive development beginning about the turn of the century. All three railways were encouraged by the provincial government which also constructed a railway bridge across the Fraser River so that timber could be delivered to mills on the north shore. Small, mobile mills grew up along the railway rights of way and, as the timber was exhausted in one area, these mills moved to another. Once the valley was cleared, the emphasis of policy shifted to enhancing farming. Although some areas of poorer soil were allowed to revert to trees, the alternative of managing the valley as a sustained yield forest was never an option.

Governmental encouragement of agricultural development was primarily indirect (once land rights had been transferred to settlers) but its encouragement of industrial development was very direct. In the case of forestry, access to government owned timber was initially restricted to the owners of sawmills. The rights to harvest were made available on flexible and financially favourable terms. Cutover lands could be returned to the government so as to ease any financial burden they might impose on the industry. A complex of large saw mills and shingle mills developed on the north side of the river and near tidewater where they had direct access to the railway and to harbours for shipping to world markets. These mills had an almost insatiable appetite for timber. Once the valley bottom was clear cut, harvesting proceeded up steep mountain slopes. Timber rights were obtained for the islands in Georgia Strait and for miles up the coast. Almost universally, the harvesting involved clear cutting with no replacement. Driven by the revenue and development imperatives, the government encouraged these activities.

Throughout, the government of BC took a short term view of forest harvesting, maintenance of forest productivity and protection of the environmental assets were not major factors in governmental policies. The reasons for this are multiple and complex but two stand out as being of primary importance. First, there was no significant constituency arguing for a more conservation oriented approach. Forests and other resources not put to some immediate human use were widely regarded as wasted. This attitude remains enshrined in legislation such as the provincial water act that accords value to water only when it is put to some human use. Second, natural resources and the environment that sustained them were considered virtually inexhaustible. Improvements in logging technology were opening more of the province to practical logging. Conserving a resource seemed unimportant when the amount was perceived to be vast and expanding.

More conservation oriented policies of forest management were not without their champions at this time. In 1909, Dr. Judson F Clark, the managing director of a large forest company, noted that experience from other regions showed that when an inexhaustible forest goes up against an insatiable demand it has

always gone hard for the forest. Dr. Clark argued strongly for sustained yield forestry. Some of his ideas about forest management were incorporated into the Forest Act of 1912, but sustained yield forestry was not one of them. Sustained yield did not become a legislative reality until after World War II.

The forest companies also were not motivated to conserve the resource on which their prosperity depended. The reason appears to be that both the markets for the forest products and the capital that developed the industry were from distant sources. In the early years of the 20th century logging was still relatively unmechanized and the trees to be harvested were huge. Getting logs to market required railways and the capital to build those railways was not available locally. The logging railways were financed by large firms with headquarters in eastern North America or Europe. The industry quickly became dominated by large enterprises usually with absentee ownership.

The primary markets for lumber and shingles were also in the east. The arrival of the Canadian Pacific Railway in 1886 opened the opportunity to supply wood products to the Canadian prairies. After 1913, changes in US tariff laws and the completion of the Panama Canal gave access to east coast US markets. Production and exports increased dramatically at this time. The environmental impact of logging and the mining of the forest resource depended to a substantial degree on events beyond the control of local governments and local businesses. Global forces helped drive the ecological transformation of the valley.

Thus, the existence of a large and accessible market provided the stimulus, foreign capital combined with technological innovation provided the means and an abundant local source of raw material coupled with favourable government policies provided the opportunity for explosive expansion of the forest industry. The result was the liquidation of the forest capital of the lower Fraser and the first great environmental transformation of the valley. Despite the apparent advances that we have made in environmental policy since that time, the same forces that propelled the first transformation are propelling the second, in which the valley is being transformed from a garden into a concrete and asphalt metropolis.

If transformation of the structure and landscapes of the lower Fraser were the primary consequence of the settlement of the valley and the exploitation of its resources there might be relatively little need for concern. However, the transformations also reflect a profound loss of ecological resources, ecological services and ecological capability. As the population of the region and the province continues to grow, these are losses that the world can less and less afford.

As we have seen, prior to European colonization the natural communities of the lower Fraser basin included the upland temperate rainforest, the wetlands of the river margin and the river itself. Temperate rainforests and wetlands are among the most biologically productive habitats on earth. The average net primary production of such forests is 550-580 grams of organic carbon per square metre of land per year ($gC/m^2/y$) and of wetlands it is 1350 $gC/m^2/y$. Primary production, which is the production of new organic material by green plants, provides the food base for all other organisms on earth and net primary production is the amount of green plant material that can be taken by other organisms without degrading the capital base of green plants. Prior to European colonization, the Canadian portion of the Fraser Lowland was comprised of approximately 2000 km^2 of forests and 1100 km^2 of wetlands. The total net primary production of the region was, therefore, about 2.7 million metric tons of organic carbon per year. Since we assume that the ecosystem was in equilibrium, this is the amount of carbon that was either consumed by other organisms living in the region or was exported by various processes from the region.

The transformation of the valley from forest to pasture and cropland with relatively small urban centres in Vancouver and New Westminster greatly altered the biological productivity of the ecosystem. Although pasture and cropland provided more products that were of direct value to humans, their average biological productivity was much lower than the natural communities that they replaced. The average net primary productivity for cultivated land is only 290-300 $gC/m^2/y$, a little more than half that of forested lands. Although intensive agriculture can push this productivity higher, early in this century intensive forms of agriculture with their high inputs of energy and fertilizers were not developed. We can reasonably

assume, therefore, that the pastures and croplands of the newly cultivated Fraser Valley did not produce more than 290 $gC/m^2/y$. The growing urban landscape produces still less biologically, about 75 $gC/m^2/y$. This is only about 13% of the productivity of the original forest community that the urban landscape is replacing.

We don't know exactly the distribution of landscapes in the Fraser Lowland during the early part of the 20th century. However, we do know that the transformation of forests and wetlands to agriculture was in full swing and that the urban centre was still relatively small. If we suppose that between 1910 and 1920 about 50% of the forest cover had been removed, that perhaps 30% of former wetlands had been diked and drained, and that the urban landscape occupied about 5% of the ecosystem, then total net primary production would have been reduced to about 2 million metric tons. We can be much more confident of the present distribution of landscapes in the basin. As we approach the 21st century, the Fraser Lowland consists of approximately 500 km^2 of forested land, 1550 km^2 of crop and pasture land, 420 km^2 of wetland, and 620 km^2 of urban land. The total net primary production of this landscape is only about 1.3 million metric tons, a little more than 40% of the productivity of the original community. Furthermore, despite their greatly reduced extent, wetlands still contribute almost half of the total biological productivity of the region (0.6 million tons). Although we cannot predict future changes with any certainty, as the second great transformation of the ecosystem from predominantly agricultural to predominantly urban landscapes proceeds, significant further losses in biological productivity can be expected.

The riverine ecosystem itself is not very productive of green plants. This is particularly true of the main-stem of the Fraser River, which is very silty. The silt reduces light penetration into the water so that green plant production is impossible except in very shallow depths. The river is dependent on primary production from elsewhere to sustain its populations of fishes and other organisms. For floodplain rivers, like the lower Fraser and its tributaries, the floodplain is an important source of organic carbon to feed the river ecosystem. The flow of the Fraser River derives primarily from snow and glacier melt in the interior of the province so that its peak flows are typically in late May or early June. The natural seasonal cycle of the river is to invade its marginal wetlands and floodplain in spring and early summer and to pick up organic material from the floodplain and carry it into the river channel and seaward to the Strait of Georgia. In the summer and fall the river flow diminishes and it retreats back into its channel. Tributary rivers and streams of the lower Fraser are, by contrast, fed primarily by winter rain storms. Their floods occur in the winter when they collect organic debris from their banks and floodplains and carry it into the main river. Thus, prior to European colonization, the river and its tributaries would have experienced seasonal pulses of high organic carbon inputs derived from the floodplain separated by periods of lower carbon input from upstream and plant growth within the river itself.

This exchange between the river and its floodplain was not all one sided. The river contributed sediments and nutrients to the floodplain during its seasonal invasions that helped sustain the high productivity of its marginal lands. The processes of flooding, channel erosion and migration, and sedimentation that were part of the normal behaviour of the river helped create the lush valley that so attracted settlement. Some of the ecological communities of the valley were dependent on the periodic inundation of the river (e.g. bulrush and cattail meadows) and others on the erosion and reworking of river islands and bars (e.g. floodplain poplar forests).

It is not possible to determine how much of the floodplain production found its way into river channels in historic times. We can say, however, that human activities in the basin have greatly altered the amount and seasonal pattern of organic carbon inputs to the river. In the first place there is the great reduction in total biological productivity of the lower Fraser described above. Furthermore, the ecosystem is presently organized to channel much of that production to human uses, not to the river. Thus, pasture and cropland production is not left to decompose and leach into the river but is harvested and put into livestock or onto supermarket shelves within and without the basin. Second, we have built an extensive system of dikes and dams to prevent the rivers from invading their floodplains. These structural changes

to the landscape have allowed humans to make greater use of the floodplain but have denied the river access to an important source of organic carbon to sustain its productivity. Third, the expansion of urban landscapes within the basin has altered the patterns of runoff from the land into the river. Urban landscapes have extensive impervious surfaces. Precipitation that would ordinarily be absorbed by the soil and released relatively slowly into streams and rivers rushes immediately through storm sewers into the waterways. These flushes carry organic materials that accumulated on streets, rooftops and parking lots between storms directly into the river in a sharp spike. The ecosystem cannot make efficient use of these concentrated but unpredictable inputs of organic material. The contribution of organic material by the floodplain to the river is, therefore, not only much lower than in historic times but is also less valuable.

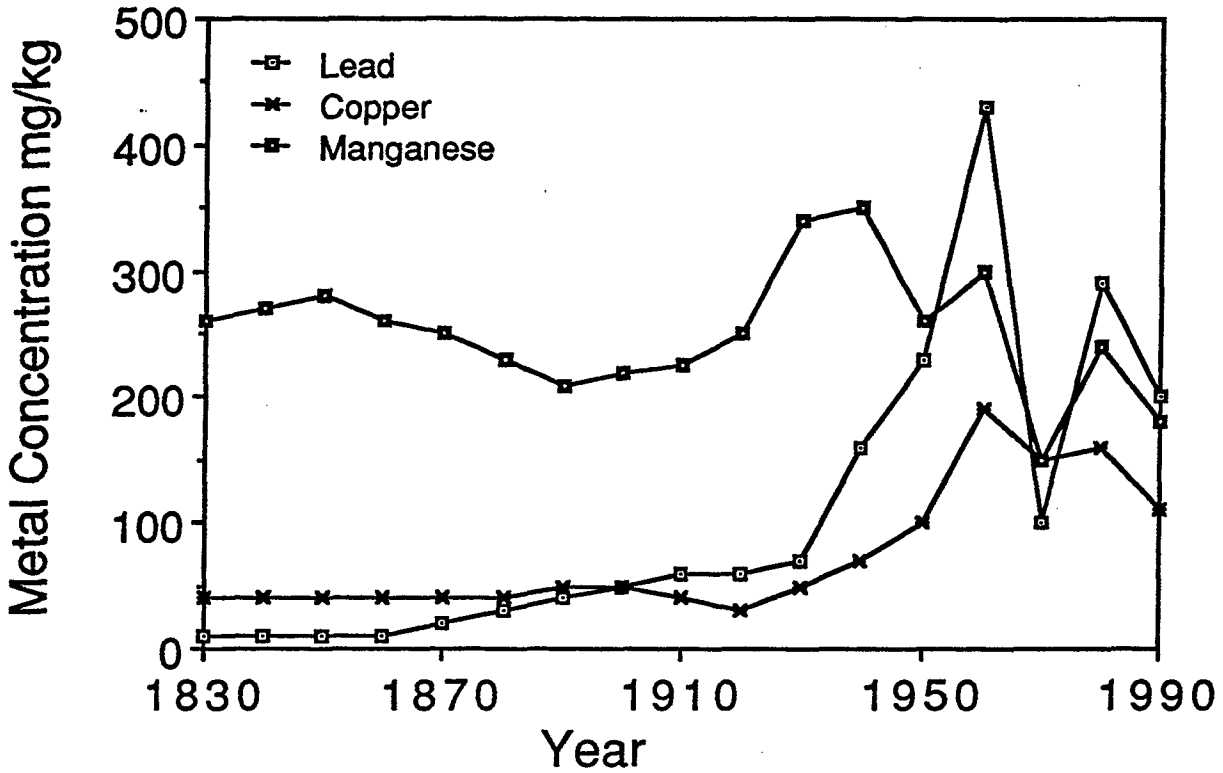
Removal of the forests, creation of farms and urbanization have also had profound consequences for the particular species that inhabit the ecosystem and how they are distributed. As an indicator of biodiversity change resulting from human occupation we undertook an historic analysis of vascular plant communities in the basin. We wanted to know how many species there were, how the number of species has changed over time and whether there had been a significant number of extinctions.

Our analysis begins in 1915 when there were 850 species known in the Fraser lowland. About 76% of these species were native and 24% were aliens, introduced primarily as a result of farming. Thus, human activity in the basin had already resulted in a significant change in the plant community by the turn of the century. Since 1915, the total number of known plant species has increased and now stands at over 1400. The number of native species has increased 43%. This change reflects a combination of new discoveries (probably resulting from more intensive collecting) and a few extinctions. One hundred and seventy-seven of the "official" rare plants of BC are known to have occurred in the Fraser lowland. We failed to detect 38 of these in recent collections or in our field sampling. It seems likely that most of these species have been eliminated from the Valley. Most of the 73% increase in plant species since 1915, however, is due to an increase in aliens, which now make up 40% of the local species. If the mountain slopes are excluded, most of the plant species in the Valley are aliens and the majority of these are common agricultural weeds from Europe.

The scale of the changes in plant diversity is very large. Other species are not so well documented but the intimate link between plant and animal communities suggests that overall species diversity must also have changed in profound but largely unknown ways.

Changes in the biological productivity of the lower Fraser, in the kinds of plant and animal communities, and in the exchanges of materials among components of the ecosystem were, of course, not the only changes brought by the changing society and economy of the basin. Changes in the chemical environment, particularly changes in the load of toxic chemicals, have been profound. Indeed, a primary concern of residents and of governments has been chemical contamination of land and water in the lower Fraser and its implications for human health. We did not attempt a detailed historical analysis of chemical contamination. We did, however, examine the history of trace metal contamination through analysis of sediments in Burnaby Lake and historical samples of moss from a variety of locations throughout the basin. The sediment analyses allow us to describe the changes in trace metal contamination of Burnaby Lake as urban and industrial land uses expanded in the basin and the use of automobiles increased (Figure 4). All trace metals analyzed showed significant increases in the sediments beginning early in the century as colonization and industrialization of the Brunette basin accelerated. Concentration of most metals peaked between 1930 and 1970 and then declined. The concentration of lead increased after 1930 with the increasing use of automobiles and leaded gasoline. Lead has declined in concentration in recent sediments, reflecting the switch to non-leaded gasoline in the 1970's. Copper shows a history of contamination similar to lead, however, the source in Burnaby Lake appears to be primarily industrial activities in the Still Creek drainage. Manganese increased sharply in the 1930's then slowly declined to background levels. On a wet volume basis, however, manganese has increased steadily since 1930. Recent increases in this contaminant may be due to its having replaced lead as an anti-knock substance in gasoline. Mercury has also increased in recent years, however, the source is unknown.

FIGURE 4
CHANGES IN THE CONCENTRATION OF SELECTED CONTAMINANTS OVER TIME IN THE SEDIMENTS OF BURNABY LAKE



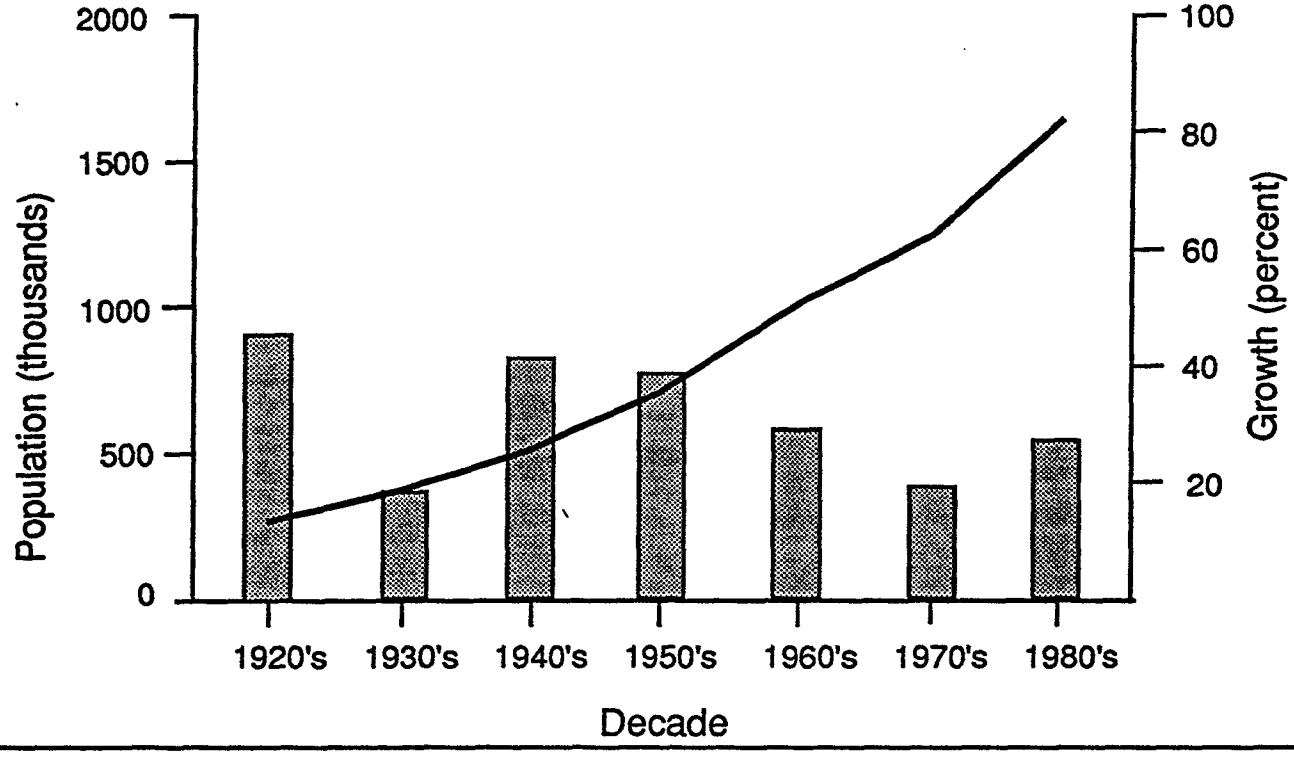
Patterns of changing atmospheric contamination were evident in our historic analysis of the moss, *Isothecium stoloniferum*, from the UBC herbarium. Mosses obtain all of their nutrition from the atmosphere, so that these analyses represent atmospheric contamination only. Lead, cadmium, chromium, zinc and nickel have all decreased in concentration in moss over the past 30 years whereas manganese has increased in concentration. The changing patterns of chemical concentration in moss reflect changing patterns of industrial activity in the lower Fraser as well as better technology for pollution control and more stringent environmental regulation. At least in the recent past, environmental regulation and technological improvements have just about been able to keep pace with the rapidly increasing population and traffic volume and we have even been able to document improvements in some aspects of the chemical environment of the ecosystem.

One of the most pressing and contentious issues of sustainability for the lower Fraser is the present rate of population growth. The region is one of the most rapidly growing population centres in North America, with a growth rate of about 2% per year. Although we tend to think of this as a present day issue, our demographic analysis shows that rapid growth of population has been a continuous aspect of society in the lower Fraser. In the 1870's the population of the valley was on the order of 7000. By 1920 it was about 250,000, an increase of almost 35 fold with decadal increases of greater than 600%. By comparison, recent decadal rates of growth have been modest, on the order of 20% to 40% (Figure

5). Furthermore, the rate of growth has, in general, been declining since the 1940's. Concerns about overcrowding, congestion, housing, and inadequate infrastructure are not new to the region.

A more insidious aspect of rapid demographic change is the social tension that it generates. Such tensions have recently generated a spate of anti-immigrant and racist rhetoric in the lower Fraser. Such racist sentiment is also a part of the history of demographic change in the lower Fraser. In the past, racism has found expression in national laws such as the 1885 Chinese Immigration Act that demanded a head tax of $50 for each Chinese immigrant. This tax was steadily increased, rising to $500 in 1903. Chinese were also denied the right to vote and to certain kinds of employment and were discriminated against in schools. As a consequence of these various forms of racism, Chinese immigration to Canada was very low from the 1920's through the 1940's. During the 1950's and 1960's there was a gradual repeal and relaxation of discriminatory immigration policy and, as a result, immigration from Asia increased dramatically.

FIGURE 5
DEMOGRAPHIC CHANGES IN THE LOWER FRASER SINCE THE 1920'S. BARS SHOW THE DECADAL GROWTH IN POPULATION IN PERCENT. LINE SHOWS THE AVERAGE POPULATION IN THOUSANDS.



Although the lower Fraser basin and its ecological transformation over the past two centuries are unique in many aspects, the main elements of the transformation are quite general. What happened in the lower Fraser has close parallels in other places. The common elements are the motivations of governments, businesses and society as they interact with each other and with the environment. From the perspective of environmental change a critical element was who had the right to make decisions about the disposition and use of natural resources. In the European style system of government introduced to the lower Fraser in the 1800's, these rights were assumed by the government. Although comprehensive government ownership of resources provided the opportunity for considered and sustainable development of the valley's forest resources, the government was not motivated to conserve resources. The imperatives to

obtain revenues and stimulate development consistently over-rode any interest the government may have had in environmental conservation and sustainable development. Furthermore, the government was concerned with encouraging colonization, which was not compatible with managing the valley as a tree farm. Nor were the business firms who harvested the resource disposed to practice either environmental or forest conservation as to do so increased the costs of production and reduced the certainty of profits. Two other participants in the first ecological transformation of the lower Fraser basin, the purchasers of forest products and the general public of the province, might have demanded environmental conservation. Consumers of BC wood products, however, had no interest in the environment of the basin, only in the availability of low cost, high quality wood products. There was and still is no effective international market for environmental conservation. To the extent that the public was concerned with environmental degradation during early development of the Valley, it was not manifest in effective broad-scale actions. Rather it was aroused by immediate and local issues, such as control of smoke and cinder emission from mills in municipalities where there was a clear fire danger and on restraining logging in watersheds to protect municipal water supply. The focus of public attention, it seems, was much more on jobs and economic expansion than on environmental conservation.

Once most of the Valley lands were transferred to private ownership, the attitudes and institutions that drove the early transformation of the ecosystem remained operative. The continuing transformation of the Valley ecosystem is rooted in another aspect of history, a definition of private property rights that does not provide for environmental conservation. The sanctity of individual property rights coupled with the underlying imperatives that drive both business and government creates a formidable obstacle to sustainable development. In addition, the rate of demographic change in the valley means that each new generation begins with a high proportion of the population (sometimes the majority) having no history or roots in the Valley and its landscapes. Thus, the collective memory that might influence the path of local development is weak. Important environmental policies have been implemented in recent years and there have been notable improvements in some aspects of environmental quality. But these improvements are almost incidental to the continuing transformation of the Valley toward a social, economic and environmental structure that is increasingly vulnerable, fragile and unsustainable.

The Present State Of The Ecosystem

Our research on the present state of the lower Fraser ecosystem emphasized the environment and society. From a certain perspective, our failure to address the economy directly (apart from our attention to the economic history of the basin) is a glaring omission. On the other hand, the economy is something to which, as a society, we continually direct our attention. Environment and society receive more intermittent and fragmentary attention. Furthermore, the economy of the basin is doing rather well. The implications of this healthy economy for environment, society and sustainability, it seemed to us, was the critical issue.

The Overall Health Of The Environment

We analyzed the state of the environment of the lower Fraser basin at three geographic scales, the basin as a whole, small watersheds and communities within the basin illustrative of different patterns of human use, and specific sites. At all three scales we find compelling evidence of environmental degradation and transformation and declining capacity to sustain human life. Although the present situation is by no means critical, a continuation of present trends (which is the basis of all our planning) is leading us directly away from environmental sustainability.

We analyzed a number of indicators of environmental health for the Valley as a whole. The most revealing of these were the nitrogen budget, plant biodiversity and the health of fishes in the Fraser River. Historical changes in plant diversity were discussed earlier. Plants are about the only large group of organisms well enough documented to provide an historical record of biodiversity. However, plant biodiversity tends to be highly correlated with diversity in other groups of organisms. We concentrated on vascular plant species because these are the most important primary producers in terrestrial

ecosystems. We now have a data base of all species found outside cultivation in the Valley, whether native or alien. The data include both the first record of the species and the last record for those species believed to be extinct as well as information on the status of each species. We also made new collections of nearly all species that still exist in the valley. These data provide an important baseline for evaluating future changes in plant biodiversity. However, the present status of many plants and recent changes in species composition are sufficient cause for concern.

There are presently 1446 vascular plant species in the lower Fraser basin and 40% of these are introduced aliens. Rare or threatened species constitute a high percentage of the native flora (Nearly 25% of native species are rare) and we are at a critical point for maintaining native biodiversity. Large natural parks have been relatively successful at preventing extinction of rare plants, but not all rare species are presently so protected and parks may not protect native species that cannot compete with alien species. Many of our rare species are wetland or aquatic species and these are in need of special attention.

The lower Fraser is experiencing an invasion of alien weeds. Most of the plant species in the lowland areas of the Valley are now aliens, mostly common weeds. The number of these species is growing faster now than ever before. More than 175 new species have been found in the Valley since 1980. This rapid invasion of plants is a clear indicator of environmental disturbance and reflects the rapidly changing landscapes and land uses in the Valley as we transform it from farmland to metropolis. Although first established in the 1930's, the recent spread of purple loosestrife in the Valley is illustrative of the present pace of change. For the past two decades, this species has been spreading at an increasing rate along waterways and roadside ditches. Loosestrife is persistent that can out compete and even eliminate native wetland species in protected as well as disturbed areas. Loosestrife has few local enemies and is of limited value to native wildlife. Although species like loosestrife can be controlled, to do so is costly. Neither our society nor our economy is presently well organized to effect such control.

Visible species, like plants, provide tangible evidence of our impact on the environment. Less visible, but more fundamental ecological processes, like nutrient cycling are also affected by human activities. Nitrogen is a critical plant nutrient and is also one of the most common chemical elements found in nature. The way that nitrogen cycles in and ecosystem is a useful indicator of ecosystem function and environmental degradation. When it is too abundant, nitrogen can overload soils and leach into waterways and aquifers where it acts as a pollutant and a public health problem. Nitrogen is a component of most hydrocarbon fuels and, when nitrogen containing fuels are burned, oxides of nitrogen are released into the atmosphere where they contribute to smog and acid rain, with ecological and public health consequences. Thus, an analysis of nitrogen budgets can provide important insights into interactions between the economy, society and the environment.

Our analysis looked primarily at agricultural uses of nitrogen and their impacts on Valley soils, waterways and aquifers throughout the basin. Agriculture is a very important economic activity in the basin. There are over 5500 farms in the lower Fraser occupying about 86,000 ha of land. Principal crops are berries, row crops, dairy, poultry and hogs. Over 50% of the value of agricultural products produced in the province comes from the lower Fraser. Yet, agriculture is being squeezed by urban expansion on the one hand and cheap imported foods on the other. As a consequence, agriculture is becoming more and more intensive with attendant high inputs of energy and chemicals and outputs of waste products. The emphasis is also shifting from dairy and vegetables to berries and poultry. Furthermore, the livestock industry, which used to be based on locally grown feeds and sell to local markets, has switched to importing feeds and exporting products. All these changes intensify local impacts and serve to decouple local agriculture from the local land base. Nowadays, a Fraser Valley farm is often little more than a housing site for the animals and a storage and disposal site for their wastes. Recent analyses had suggested that nitrogen levels in some aquifers used for domestic water supplies were above the allowable nitrogen concentration for human consumption. We wished to determine the extent of the contamination problem and whether agriculture was to blame.

We used a mass balance model for nitrogen to assess nitrogen budgets for the four regional districts in the Valley (Fraser-Cheam, Dewdney-Alouette, Central Fraser, and Greater Vancouver. The first three have subsequently been amalgamated into one regional district, the Fraser Valley Regional District). The sources of nitrogen that we considered were animal manure, inorganic fertilizers, atmospheric deposition and biological fixation. The sinks for nitrogen were uptake by crops and denitrification, which releases elemental nitrogen back into the atmosphere. The excess of inputs of nitrogen over outputs was the amount of nitrogen that could leach into aquifers and waterways. Our analysis considered the period 1971 to 1991, so that we could assess trends in nitrogen dynamics.

Nitrogen inputs to the Valley increased steadily from 1971 to 1991. Estimates of leachable nitrogen were negative or negligible prior to 1971, indicating that the system was capable of absorbing all of the inputs. Since 1971, however, the estimate of leachable nitrogen has grown ever more rapidly. The Central Fraser Valley Regional District is the biggest contributor and this region has recorded an excess of nitrogen since 1971. The Central Fraser Valley is also the region with the most intensive agricultural development. The Rural districts of Fraser-Cheam and Dewdney-Alouette did not record a surplus of nitrogen until after 1976 and the Greater Vancouver District not until after 1981.

Increasing concentration of nitrogen in aquifers since 1971 reflects the increasing oversupply of nitrogen to soils in the Valley. Nitrogen was not detectable in aquifer samples taken in 1971 (except in the Central Fraser Valley) but by 1991 average concentrations throughout the valley were 6 mg/l. Concentrations vary considerably among districts ranging from a low of 1.7 mg/l for samples from the Dewdney-Alouette region in 1991 to 13.6 mg/l in the Central Fraser Valley (Fraser-Cheam concentrations were 7.4 mg/l and Greater Vancouver concentrations were 3.2 mg/l in 1991). The maximum acceptable concentration for nitrogen in drinking waters is 10 mg/l. Although individual wells vary considerably, average groundwater concentrations have exceeded 10 mg/l in the Central Fraser Valley since 1981.

Animal manure is the principal source of nitrogen throughout the basin. The biggest contributor was cattle farms (mainly dairy) which provided between 4922 and 5805 tons of nitrogen/year. By comparison, poultry farms contribute 1331-1789 tons/year and pig farms 103-677 tons/year. Hog and poultry farming is increasing in the valley, however, with the adoption of intensive industrial methods, whereas cattle farms are stable or declining. The nitrogen from farm animals is not evenly distributed over the valley or over the areas of farm land so that average amounts of waste do not reflect the true level of contamination in the heavily used areas. In the most intensively farmed areas, such as Sumas Prairie, animal stocking densities exceed 5 animal units per hectare (1 animal unit equals 1000 lbs of animal mass and is, therefore, part of 1 cow but many chickens). This stocking density exceeds recommended levels for effective manure management by up to 2 times (Several European countries have regulations limiting stocking to a maximum of 2.5 to 2.7 animal units/ha).

Fertilizer applications represent another important source of nitrogen in the basin. Whereas spreading of animal manure adds about 205 kg/ha of nitrogen each year, inorganic fertilizer applications add an additional 68 kg/ha. The total application rate of 273 kg/ha/yr greatly exceeds typical rates of nitrogen application in other agricultural areas. The total application rate also exceeds the capacity of the soil to absorb the nitrogen and of crops to take it up. The excess nitrogen accumulates in aquifers and is discharged into streams. All streams draining agricultural areas have nitrogen concentrations above background levels. In the mainstem Fraser, however, because of its huge dilution effect, there is no measurable increase in nitrogen concentrations due to leaching from agricultural lands.

Our conclusion is that heavy manure and fertilizer applications, highly intensive and geographically concentrated agricultural operations, and inadequate animal waste management are the primary cause of nitrogen pollution in groundwaters of the lower Fraser. In the central Fraser Valley the problem is acute with more than 50% of wells in the Abbotsford area testing in excess of 10 mg/l nitrogen The well waters of the Central Fraser Valley, thus, pose a health hazard if used for domestic consumption. Furthermore, nitrogen is an indicator of the presence of other important chemicals used in agriculture and other human activities. We conducted less thorough analysis of some of these chemicals (e.g. the

nutrient phosphorus and the greenhouse gases carbon dioxide and methane) and the results echo those for nitrogen.

As a further broad scale indicator of the environmental health of the lower Fraser we have examined the fish populations of the main-stem Fraser River and some of its tributaries. Aquatic organisms are good indicators of environmental health because they are integrators of both land and water pollution. Also, in the case of the main-stem Fraser, we had a 20 year old data base on the abundance and composition of the fishes that provided a benchmark against which to compare our present samples. Our analysis, therefore, examined the abundance and species composition of resident fishes in the main-stem Fraser, the abundance and species composition of resident fishes in small tributaries in regions of different land use activity, and pathological and toxicological analyses of fishes in the main-stem Fraser. The latter analysis was part of a collaborative study with the Fraser Estuary Management Program.

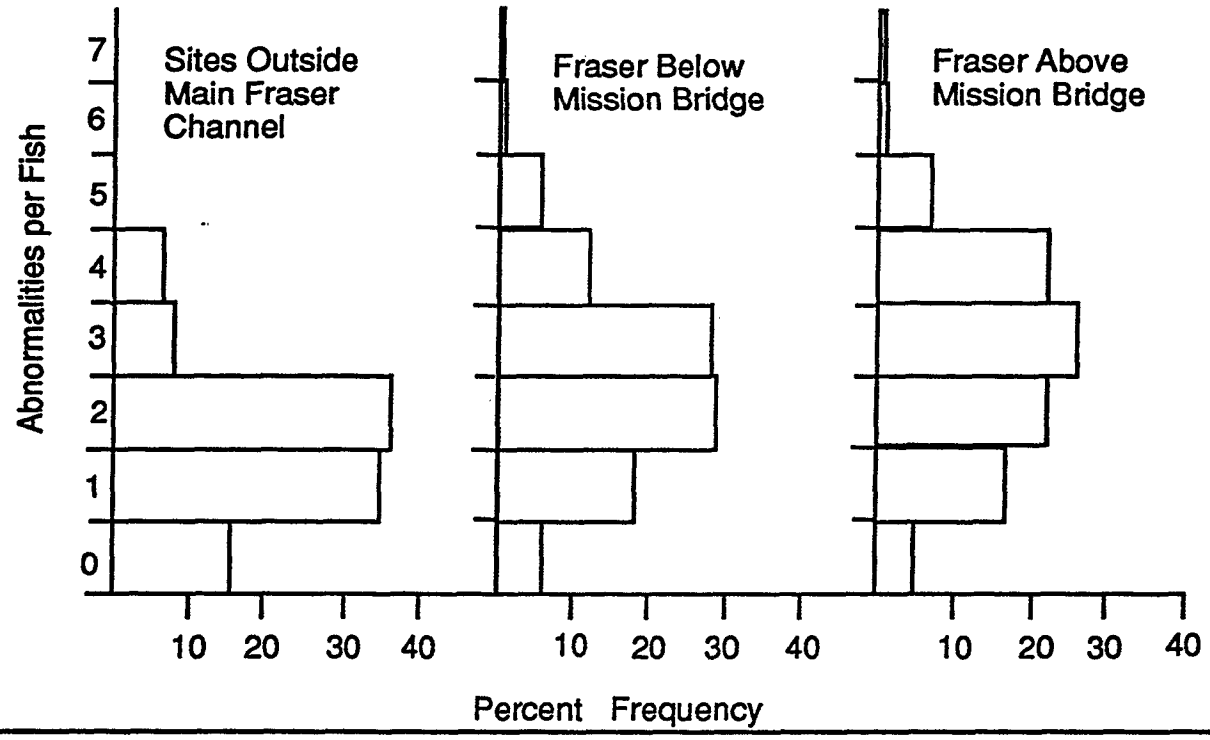
We found 38 species of fishes in the lower Fraser River; 21 resident species (three of which are introduced; carp, brown bullhead, black crappie), 10 transient marine species that invade the estuary and lower reaches of the river and 7 anadromous species (including the 5 species of Pacific salmon). Species composition of the main river has not changed over the 20 years for which we have records, however, most species were more abundant than 20 years ago. The exception was the largescale sucker, which was no more abundant than in the 1970's. Although the fish were more abundant in our samples, they were also smaller in size so that the total weight of fish caught was no different than in the 1970's.

Many fewer species were found in the tributary streams and rivers (number of species ranged from 3-12), however, sampling in the tributaries was concentrated at a single time period and was not designed to provide a complete species list. Comparing among tributaries, we found no consistent relationship between the degree of human alteration of the tributary and number of species captured. In the three most intensively studied tributaries, however, (Brunette, Sumas and Salmon Rivers, Fig 3) both overall abundance of fishes and species composition were related to human impacts. The Brunette is heavily urbanized and some portions are seriously contaminated by non-point pollution from urban run-off. Fish were scarce in the Brunette, even in less degraded sections, and pollution tolerant species (stickleback, sculpin, carp) dominated (making up 73% of total fish weight). The Sumas is also a degraded system with contamination primarily from agriculture but also from natural sources. Pollution tolerant species were also most abundant in the Sumas, making up 86% of the biomass but total biomass was significantly greater in the Sumas than in the Brunette. By contrast, the Salmon River, which is still relatively pristine in its middle reaches, has a fish community dominated by salmonids (52%) and had the greatest fish biomass of the three tributaries.

Although fish appear relatively healthy in the Fraser in terms of species and abundance, we found a surprisingly high number of gross pathological abnormalities in individuals larger than 10 cm (the smallest size on which we could successfully perform an autopsy) (Figure 6). Gross pathologies refer to visible abnormalities of the skin, fins, eyes, gills and pseudobranch (a small patch of highly vascular tissue near the gills) externally and liver, kidney, spleen and gut internally. The most common abnormalities were discolouration and lesions in the liver and kidney and clubbing and discoloration of the gills. More than 90% of fish from the Fraser had at least one visible abnormality while more than 80% of fish from tributaries and lakes away from the main channel had at least one abnormality (Figure 6). Abnormalities were most common in fish from upstream sampling locations (Hope to Mission), slightly but significantly less common in downstream locations (Mission to the river mouth), and considerably less common in samples taken outside the main-stem Fraser. Abnormalities also change seasonally in the Fraser, being significantly more common in spring than summer. It is a matter of concern that these abnormalities are more common in Fraser fishes than in other urbanized water ways.

The causes of these pathological abnormalities and their significance for the fish are not well understood. They are believed to indicate that the fish are subject to environmental stress but provide few clues as to what that stress might be. Liver discolouration, the most frequently observed abnormality, is often an indicator of fat accumulation in the liver suggesting metabolic abnormalities that could be linked to growth

FIGURE 6.
INCIDENCE OF PATHOLOGICAL ABNORMALITIES IN LOWER FRASER RIVER FISHES



and reproduction. Largescale suckers, which were depressed in abundance relative to the other species, had the highest incidence of liver abnormalities. Two of the species from the lower reach of the Fraser, starry flounder and peamouth chub, were analyzed for a broad spectrum of toxic chemicals as part of the Fraser River Action Plan. The results of this analysis showed very low concentrations of individual toxic substances in the tissues of the fish but confirmed the presence of many toxic chemicals in all tissues. If the body burden of toxic chemicals is inducing the pathological abnormalities it must be by the cumulative effects of many chemicals at low concentration. On the other hand, the fact that the incidence of pathological abnormalities was greatest in the upstream portion of the lower Fraser indicates that naturally occurring stressors cannot be ruled out as the cause of the pathologies. Furthermore, comparison with analyses done in previous years suggests that the chemical environment for fishes is improving in the lower Fraser. Chemical analyses, therefore, suggest that the environment of the lower Fraser is acceptable for fish and is improving over time whereas the gross pathologies suggest that something may be seriously wrong. We are continuing to investigate the implications of these pathological abnormalities for the health of the fishes and their value as indicators of environmental health.

At present, although it appears that intensive human activities have affected the abundance and species composition of fishes in tributary streams we are unable to draw unequivocal conclusions about the fishes in the main river. On the positive side, fish remain abundant in the main river. Although there have been some introductions of alien species to the region, there has not been a wholesale transformation of the fish community as there has been of the plant community. The high incidence of abnormalities in the fish, however, and the apparent changes in tributary fish communities warns us that we cannot be complacent about the health of the aquatic ecosystem.

Health of Small Watersheds

Our research on small watersheds provided a more detailed look at economy/environment/society interactions at smaller geographic scales. The results provide further insights into the complexity of this interrelationship. Most intensive research was conducted on the Brunette River in Burnaby, the Salmon River in Langley Township and the Sumas River in Abbotsford. For all three watersheds the emphasis was on non-point sources of pollution and the impact of land use on water and sediment quality. The research was particularly directed at assessing the effects of storms on the input and distribution of contaminants and, in the rural watersheds, the impact of farm wastes and septic systems on groundwater contamination. Other watersheds were less studied but provided important comparative information particularly with regard to some of the biological variables investigated.

The Brunette River Watershed

The Brunette watershed is a highly urbanized watershed in the north western part of our study area (Figure 3). Most of the watershed is within the municipality of Burnaby but the catchment also extends into Vancouver, New Westminster, Coquitlam and Port Coquitlam. Burnaby Lake, near the centre of the catchment is the principal hydrological feature of the watershed. Tributaries of Burnaby Lake include Still Creek that drains about 1/3 of the catchment in the north west, Deer Creek that drains 32 ha Deer Lake to the south and Eagle Creek that drains the western slopes of Burnaby Mountain to the north. Burnaby Lake discharges into the Brunette River that flows east and south to the Fraser. Stoney Creek is an important tributary of the Brunette River that drains the steep slopes of Burnaby Mountain in the north east corner of the watershed. The catchment is approximately 7.2 km^2 in area.

Prior to 1850, the catchment was a forested hunting area for Squamish and Kwantlen Indians. Following European immigration in the 1860's until 1900 the watershed was logged and converted to agriculture. Extension of the Great Northern Railway and street car service from New Westminster to Vancouver in the first decade of the new century allowed residential development to proceed in the watershed. Following the second World War, land along Still Creek was zoned for industrial development, initiating a period of commercial and industrial expansion that continues to the present. Absolute growth in population peaked during the decades of the 1950's and 1960's and established the present urban/industrial character of the watershed. Present population of the catchment is about 156,000 or 21.7/ha. Zoned land uses in the catchment are approximately 50% residential, 26% industrial/commercial and 23% park and open space. Principal park and natural spaces are located around Deer Lake, Burnaby Lake, the lower reaches of Still Creek and on the steeper slopes of Burnaby Mountain. The parks and their associated aquatic environments are highly valued by local residents and there is considerable participation in community based environmental stewardship.

Historically, the Brunette system has been used for the discharge of industrial and domestic wastes but this is no longer the case. Permitted industrial discharges are a relatively minor potential source of contamination in the watershed. Two industrial tank farms discharge treated stormwater into Eagle Creek. Solid wastes are either taken out of the watershed or are burned at the Burnaby incinerator facility. A regional landfill (now closed) near the Brunette River discharges its leachate to the Annacis sewage treatment plant outside the watershed. Hazardous wastes generated inside the watershed are either stored or transported outside the province for disposal. The primary sources of potential contamination of the watershed are stormwater runoff from urban and industrial areas (we have documented 160 storm sewer outfalls distributed throughout the basin), atmospheric deposition and leaking or illegally discharging domestic or industrial waste systems.

The problems of sustaining natural ecosystem values in a highly urbanized watershed are well illustrated by the Brunette system. Since a central issue of environmental management in the Brunette is control of non-point sources of pollution in storm water runoff, it was to this issue that we directed our attention.

In late summer, we collected stream and lake bed sediments at more than 30 locations throughout the watershed and street sediments at 25 locations representative of different land use and vehicular traffic activity in the basin. In addition, we routinely sampled water and suspended sediment from thirteen stations in the principal waterways during base flow (low flows between storm events), including five on Still Creek, two each on Deer Creek, Eagle Creek and Stoney Creek and two on the main Brunette River. We also monitored three of these stations (two on Still Creek and one on Eagle Creek) during storm events to determine in detail how storm runoff brought contaminants to the stream channels. During storm events, water running along the streets was also sampled at four locations. These samples were analyzed for trace metal, organic, nutrient and bacterial contaminants.

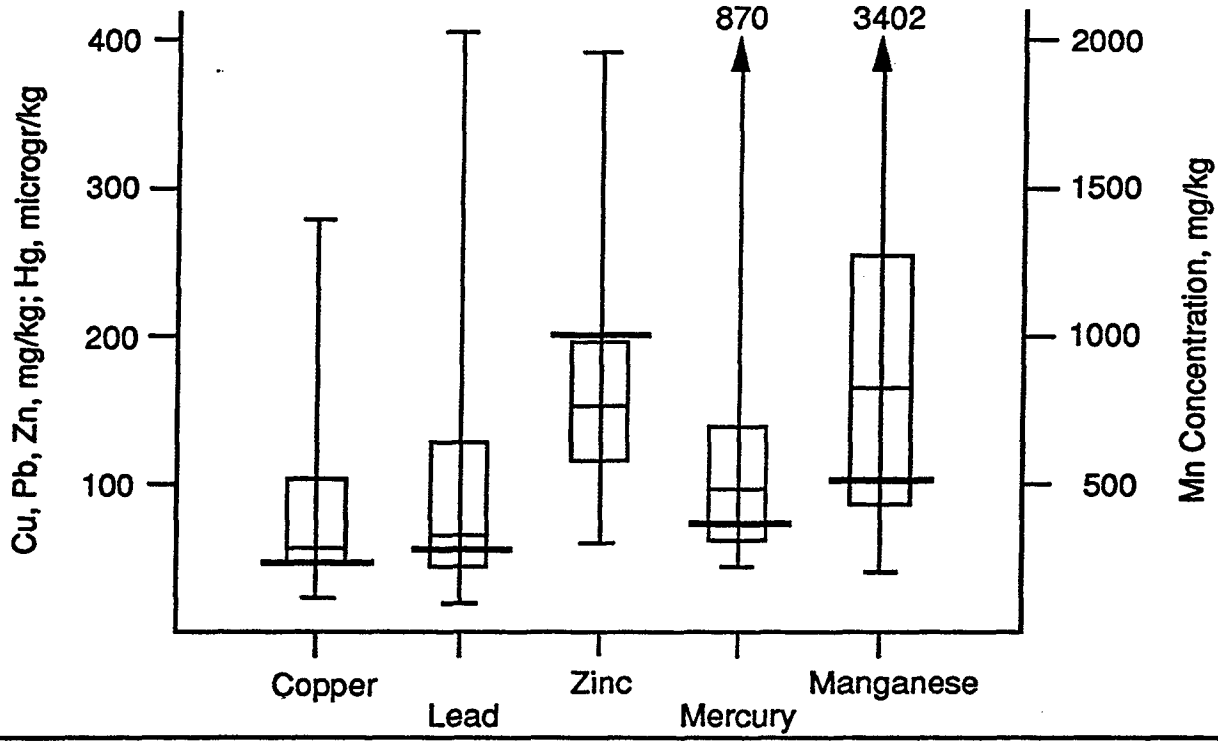
Considerable variation in metal contamination occurs throughout the Brunette watershed and many metals occur in relatively high concentration (Figure 7). Concentrations of lead, copper and zinc were high everywhere but the Still Creek area was the most highly contaminated. Much of the metal was in extractable and bio-available forms suggesting predominantly human sources for the contamination. Manganese was also high throughout the basin but was not in greatest concentration in the Still Creek area. Much of the manganese is also in extractable form suggesting anthropogenic origins. With the exception of mercury, other trace metals appear to be primarily from natural sources. The source of the high mercury concentrations is unknown but may be in part atmospheric fallout from the Burnaby incinerator as well as fossil fuels and domestic and industrial chemicals. Based on comparison with sediment samples taken in the early 1970's, lead has decreased significantly in sediments whereas manganese, copper, zinc and mercury have all increased dramatically.

Dirt on streets that washes into the rivers during rainstorms appears to be an important source of metal contamination. In particular, lead, zinc, copper, nickel and chromium are in high concentrations in street dirt. However, runoff from streets cannot account for the whole of non-point contamination in the Brunette as some contaminants are not particularly prevalent in street dirt (e.g. mercury and manganese). Analysis of street sediment contamination in relation to land development, degree of impervious surfaces, industrial activity and traffic volumes shows that streets within greenspace consistently have the lowest levels of contamination. Comparisons with traffic volume suggest that traffic makes an important contribution to lead and chromium contamination. Unfortunately, this analysis did not allow us to rule out traffic as a source of other contaminants. Comparison of stream sediment contamination in the Brunette and Still Creek sub-basins provides further evidence that traffic and degree of impervious surfaces contribute substantially to contamination by lead, copper and zinc. Industrial and commercial uses of land appear to be less significant as contributors to contamination by trace metals.

Analysis of water quality during base flows in the river systems and flushes of contamination entering with rainstorms illustrates present day human impacts on the Brunette system. Dissolved oxygen levels in the water during summer are often depressed particularly in the upper and lower reaches of Still Creek and the Brunette River downstream from Burnaby Lake. These same reaches show acceptable dissolved oxygen concentrations during higher winter flows. Reduced oxygen in summer is a consequence of higher temperatures, biochemical oxygen demand and benthic oxygen demand. Nutrient concentrations were high in Still Creek, ranging up to 2.6 mg/l nitrate (NO_3), 1.12 mg/l ammonium (NH_3), and 190 micrograms/l soluble reactive phosphorus. NO_3 concentration declined from the headwaters of Still Creek to Burnaby Lake whereas NH_3 values were highest in the lower reaches of Still Creek. Phosphorus was high in both the headwaters and near the mouth of Still Creek. Nutrient concentrations in other parts of the Brunette system were much lower. High nutrient levels in Still Creek suggest that periphyton growth is not sufficient to strip nutrients from the water. Measures of diurnal variation in oxygen concentration in the upper reaches of Still Creek further suggests a low level of autotrophic activity in this system.

Fecal coliforms were in high concentration in the Brunette system during both summer and winter. Highest concentrations were in Still Creek where summer concentrations often exceeded 100,000 coliform units per 100 ml. Concentrations were much lower in other parts of the basin. The high values

FIGURE 7.
CONCENTRATIONS OF COPPER, LEAD, ZINC, MERCURY AND MANGANESE IN STREAM SEDIMENTS OF THE BRUNETTE BASIN.
Vertical bars show the range of concentrations measured, the box encloses the concentrations within which 50% of the samples fell and the thin horizontal line within the box shows median concentration. The heavy horizontal lines show concentrations considered heavily polluted by US EPA for the Great Lakes, except for mercury, which is the Brunette watershed objective.



in Still Creek appear to originate from cross connections between domestic sewers and storm sewers or leaking domestic sewer lines.

We analyzed water samples for copper. lead, zinc and manganese. Although the concentrations in the water samples were much lower than those observed in sediment samples reported above, many samples still exceeded water quality objectives established for these substances within the basin by Provincial authorities. Lead exceeded the criteria only twice in 65 samples, however, zinc exceeded the criteria in 22 of 116 samples and copper in all samples. The water quality objective for copper is very low, however, near the detection limit, and so is of limited value for determining variation in water quality.

Values for virtually all water quality parameters were increased in storm flows compared with base flows and total export coefficients were also higher. Street run-off values and export coefficients were also high relative to base flow and were sometimes higher than storm flows. Summer storms had higher concentrations of contaminants than winter storms, presumably because the higher frequency of winter storms allowed less time for contaminants to accumulate between storms. More heavily developed portions of the basin also had higher concentrations of contaminants in the storm flow, presumably because of the greater amounts of human activity and higher percentage of impervious surfaces in these areas. Thus, storm flows contribute a very high proportion of the total loading of contaminants to the river system and concentrations during storm events are typically much higher than base flow concentrations. Base flows, therefore, offer a misleading picture of the concentrations of contaminants to

which aquatic life is subject as short term exposure during storm events can be more than an order of magnitude greater.

In common with many other urban watersheds, the stream and lake sediments of the Brunette basin are contaminated to varying degrees with a range of trace metals, organic substances and fecal coliforms. The Brunette has higher concentrations of these contaminants than the rural streams that we have analyzed within the lower Fraser basin. Stormwater runoff appears to be the primary source but atmospheric fallout also contributes to contamination in the Brunette and other watersheds of the lower Fraser basin.

The flows of lead, copper and zinc into Burnaby Lake are high relative to comparable urban lakes in Seattle, Washington and Melbourne, Australia. With few exceptions, concentrations of lead, copper and zinc in sediments of the Brunette system exceeded US EPA criteria for heavily contaminated sediments and exceeded BC objectives for mercury. Several organic pollutants, nutrients and fecal coliform concentrations are also above background levels in parts of the basin and, in some instances, above levels acceptable for many forms of water use. Dissolved oxygen concentrations are depressed in several reaches. One can only conclude that the Brunette River ecosystem is seriously degraded, not only in comparison with pre-development times but also in comparison with urban streams in other parts of the world. The majority of the contamination is generated by ordinary human activities within (street run-off) and outside (atmospheric fallout) the basin.

Important consequences of this contamination are lost ecological, economic and amenity values. Deer lake, once a popular swimming lake, is now closed to swimming due to fecal coliform contamination. Channelization and enclosure of streams in storm sewers have reduced the visual and landscape values that derive from open and vegetated streams. Fish are often used as a sensitive indicator of ecological integrity. In comparison with other small watersheds, the Brunette has few species, fish are few in number and species composition was shifted strongly toward pollutant tolerant species. Coho salmon and trout were once abundant in the watershed but have been virtually eliminated. Attempts to reestablish coho in the Brunette River and Stoney Creek have met with only limited success. In terms of these lost values, the Brunette is typical of most urban streams. There are options for maintaining and even enhancing the ecological, economic and amenity values of such urban watersheds, even in the face of increasing human density and land use. If we are serious about sustainable development then we must take these options seriously.

The Sumas River Watershed

The Sumas River watershed occupies about 34.3 km^2 in the south central area of our study area. It originates in Washington State (17.7 km^2 in the US) and flows north to join the Fraser River east of Abbotsford in British Columbia (16.6 km^2 in Canada) (Figure 3). The watershed comprises a long flat valley bordered by steep slopes of Sumas Mountain to the northwest and Vedder Mountain to the southeast. The valley averages about 5 km wide and is about 35 km long. The valley floor is approximately at sea level while the adjacent mountains rise to about 800 m. The valley was an arm of the sea during much of the Quaternary period, during which time marine sediments more than 300 m deep were laid down. These were later topped with less than 5 m of post-glacial deposits from Sumas Lake.

Within Canada the Sumas River flows across "Sumas Prairie", the bed of a shallow lake that was drained early in the century to create farm land. After crossing the US/Canada border, the main Sumas River meanders north and west across the valley floor for about half the distance to its outfall. In this reach it is augmented by two principal tributaries, Marshall Creek draining a gravely ridge to the west and Saar Creek draining the slopes of Vedder Mountain. It encounters the base of Sumas Mountain about 10 km from its mouth and completes its course along the base of the mountain on the northwest side of the valley. In this reach it receives a number of small tributaries from the steep slopes of Sumas Mountain and the Sumas Lake Canal from the south that drains the main portion of the old lake bed.

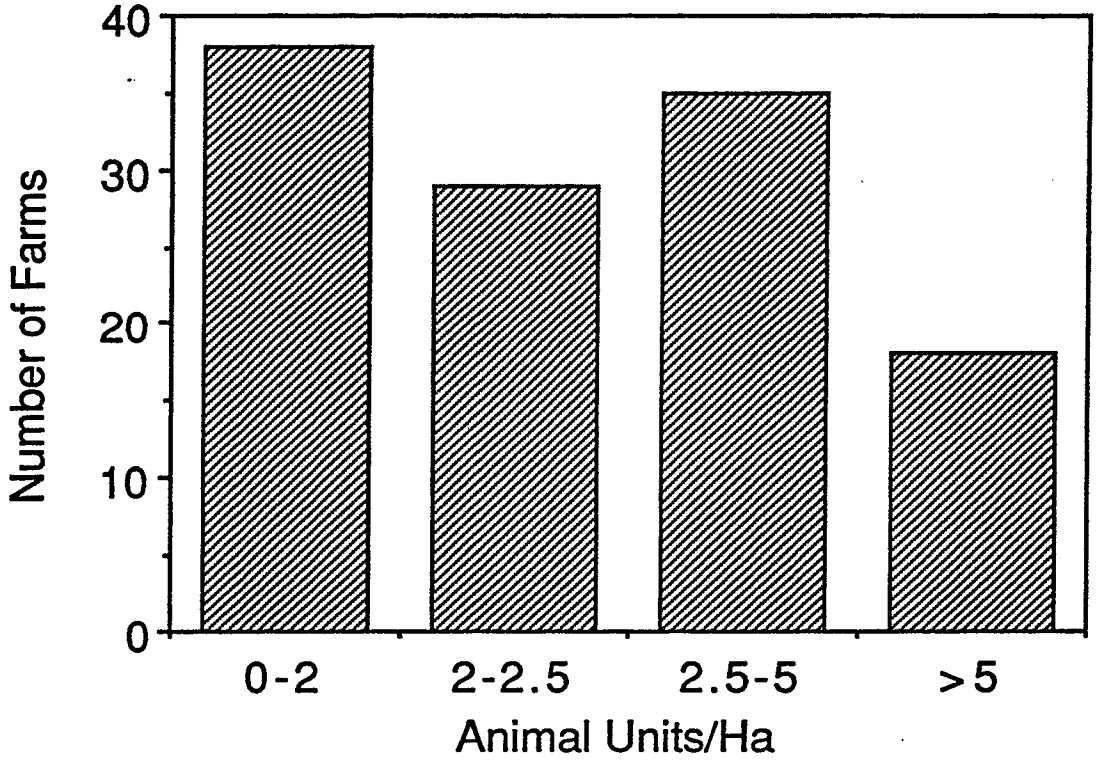
Sumas Prairie is one of the most productive and intensively farmed agricultural areas in BC. Predominant soil features are sandy lake bottom sediments in the northeast portion of the valley and gravel deposits in the west. Dairy and pasture with some vegetable production were the most common agricultural activities until recently when there began a considerable increase in poultry and hog production and in sod farms. The city of Abbotsford is expanding rapidly on the mountain slopes around the lowland farming area to the north and west. Land use in the valley is presently about 59% agriculture, 27% forest, and 8% urban/industrial. Agriculture and urban/industrial lands contribute a variety of pollutants to the valley and the Sumas River. In addition, sediments rich in asbestos and trace metals are eroding from the headwaters and being transported to the floodplain. The Sumas watershed, thus, suffers from a variety of environmental problems including chronic flooding of the lowlands and degraded soil and water quality associated with natural and anthropogenic contamination of the land and water. Our analysis of the environment of the Sumas Watershed looked at present land uses and their impacts on trace metals, nutrients and ecological integrity in the Sumas ecosystem.

We collected stream bed sediments from 23 sites distributed throughout the Canadian portion of the basin in August of 1993 and 1994. These samples were used to determine trace metal contamination patterns in the basin. We took water samples at 16 stations throughout the basin eight times during 1993-1994 to assess changes in water quality over the annual cycle. We also sampled fecal coliforms at three of these stations. Information on soils and land use was taken from published sources. We determined locations and sizes of farms and farming activities from published sources, aerial photos, on site surveys and agricultural census data from Statistics Canada.

The Sumas watershed is changing rapidly. This makes any characterization of the watershed difficult as there is no fixed point of reference. Although the agricultural land base is fixed (in fact, it may be declining somewhat due to occasional removals from the agricultural land reserve), the intensity of farming activity is increasing. The number of farms is increasing (283 in 1994 and increasing at a little less than 1% per year), as is the number of farm dwellings (a little over 1000 in 1991 and increasing at slightly more than 1% per year). The number of poultry is increasing (about 500,000 in 1991 with recent increases of more than 11% per year) as is the number of hogs (about 38,000 in 1991 with recent increases of almost 9% per year) but the number of dairy cattle is fairly stable. The increasing number of farm animals in the valley creates a serious animal waste management problem. Most farmers dispose of their manure on their own or adjacent leased land. Some manure, in particular poultry manure, is exported from the valley. To permit comparison of farming activities that involve different kinds of agricultural animals, animal types can be converted to "equivalent units" based on the amount of nitrogen waste they produce. Given the soil types in the valley we made a conservative estimate that farms in the Sumas Prairie can absorb the waste from about 2.5 animal units per hectare. Beyond this stocking density nitrogen contamination of soils and water is likely to become an increasing concern. About 40% of farms have animal densities greater than 2.5 animal units/ha (Figure 8). Although the average density over the whole farmed area is only now approaching the level at which contamination is likely to become a general problem, there are already many locations within the valley where waste applications exceed the absorptive capacity of the soil. The excess nitrogen is leaching into groundwater and into the Sumas River and its tributaries.

Like most local watersheds, the flow of the Sumas River is dominated by winter rainstorms with low summer flows maintained by outflow from aquifers in the basin. The adjacent Fraser River, into which the Sumas River drains, is dominated by snow melt in the interior of British Columbia and has peak flows in the late spring and early summer. These contrasting hydrographic regimes coupled with the low elevation of the Sumas Prairie creates a complicated water management problem in the valley. Flooding of low lying areas is prevented by a network of dikes, canals and a large pump station at the mouth of the river. In early to mid May the flood gates at the mouth of the river are closed and the Sumas River is pumped across the dike into the Fraser River. This prevents the Fraser flood from inundating the Sumas Valley. The flood gates are kept closed until September 15 so that Sumas River water can be used primarily for irrigation in the valley. The floodgates are opened in September to permit upstream

FIGURE 8
FREQUENCY OF INDIVIDUAL FARMS HAVING VARIOUS ANIMAL DENSITIES PER HECTARE. A DENSITY OF 2.5 ANIMAL UNITS/HA IS CONSIDERED THE DENSITY AT WHICH NITROGEN CONTAMINATION FROM MANURE IS LIKELY TO BECOME A PROBLEM.



migration of salmon. The gates are left open all winter unless the water levels in the Fraser River or Vedder Canal rise 3.5 m above the local datum.

Flooding has been a continual problem in the valley, particularly from the Nooksack River in the US, which occasionally floods into the Sumas watershed and affects particularly the southwestern portion of the valley. Control and prevention of this flooding is an issue of both local and international concern. Excess water is not the only concern, however. The southwest corner of the Sumas basin overlies the Abbotsford aquifer. This aquifer provides drinking water for most of the Sumas Prairie and the city of Abbotsford, irrigation water for large parts of the Sumas Prairie and water for a major Provincial fish hatchery. This aquifer is vulnerable to contamination by improper management of farm and urban wastes. Contamination is already evident as 60% of samples taken from one region of the aquifer had nitrogen concentrations that exceeded the acceptable maximum for drinking water of 10 mg/l.

As with the Brunette River, non-point sources of water and sediment contamination are the principal problems in the Sumas drainage. There are three permitted point-source outfalls into Marshall Creek and, thus, into the Sumas River on the Canadian side of the border. These include a discharge of cooling water from an evaporated milk plant, a discharge of effluent from a slaughterhouse that drains into Marshall Creek via a small ditch, and discharge of waste water from the Provincial trout hatchery via a

containment lagoon. None of these effluents appears to have a large effect on water quality within the Sumas system. On the US side of the border, the major permitted outfall is the sewage discharge from the town of Sumas. This outfall is monitored daily and meets the water quality criteria established by the Washington Department of Ecology. It is doubtful that the Sumas sewage outfall is a significant source of the water and sediment quality problems observed downstream.

We measured concentrations of the trace metals cadmium, lead, chromium, copper, nickel, and zinc in the sediments of the Sumas drainage system. Cadmium and lead were below detection and values for the other metals were within the range of values for sediments from elsewhere in the region except nickel, which had median concentrations between 149 and 171 mg/kg of sediment. Nickel contamination in this watershed is not of human origin but comes primarily from a natural source, an eroding hillside on Vedder Mountain. Although the concentrations of chromium, copper and zinc are within the natural range for sediments in the region, they are also within the range of criteria for moderately to heavily polluted sediments. Copper and zinc appear to be the two metals most influenced by human activities (Figure 9). Most values for copper were more than 16 but less than 50 mg/kg, the tentative limits for no effect and heavily polluted as established from Provincial guidelines and the US EPA respectively. Similarly, most values for zinc were more than 120 but less than 200 mg/kg, the tentative limits for no effect and heavily polluted. Concentrations tended to be higher in tributaries than in the main Sumas River, with highest values in sediments of irrigation ditches, suggesting agricultural inputs. Nickel and chromium contamination peaks at the inflow from Swift Creek (the source of the metals) on the US side of the International Border and declines sharply as one moves downstream.

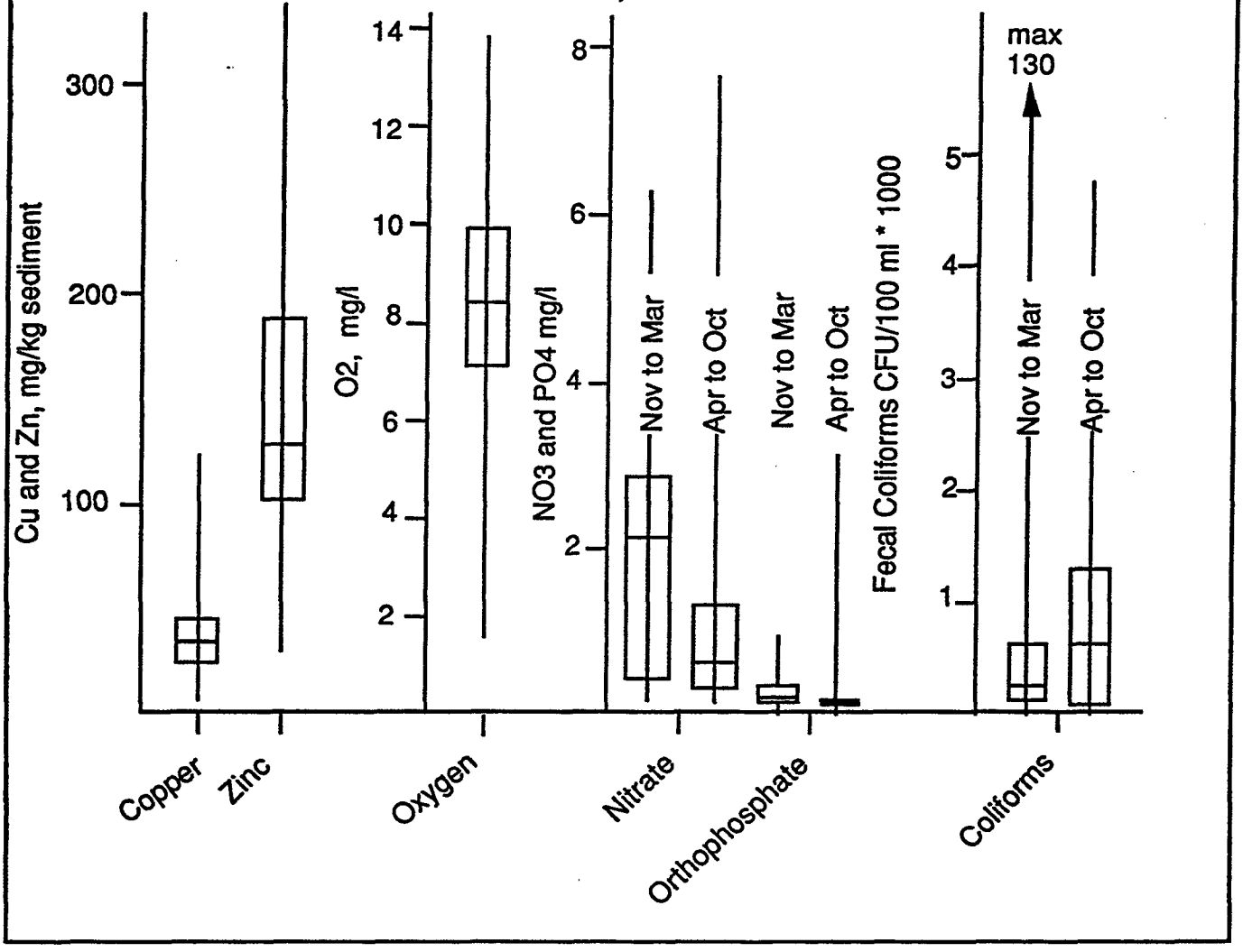
Dissolved oxygen in stream channels was typically in the range 6-10 mg/l, usually at or just above guidelines for stream dwelling salmonids but below provincial guidelines for egg and alevin stages. Oxygen concentrations of < 3 mg/l were observed in some locations (Figure 9). Values this low would cause serious problems for salmonids and many other fishes if they were unable to migrate to areas of higher oxygen. Arnold slough, which drains the southwestern portion of the old lake bed, has persistently low oxygen values during the late summer and fall. Dissolved oxygen values were negatively correlated with surplus nitrogen applied to adjacent lands indicating an important link between nutrient loading, agricultural runoff and oxygen depletion in the Sumas watershed.

The nutrients nitrate (NO_3) and orthophosphate showed seasonal trends in the Sumas, being generally in higher concentrations in winter (the wet season) than summer (the dry season) (Figure 9). Dry season values for both nutrients are higher than in the Brunette, suggesting greater nutrient loading to the Sumas. Nutrients show a number of spatial patterns. During the dry season, concentrations increased from headwaters to the US/Canada border and then decreased downstream. Marshall Creek was consistently high in NO_3 and, in contrast to other parts of the watershed, values were higher in the dry season than in the wet season. This is probably due to inputs of NO_3 to Marshall Creek from the Abbotsford aquifer. During the wet season, concentrations of ammonia were strongly correlated with the amount of surplus nitrogen applied to adjacent lands and cattle densities, concentrations of NO_3 were associated with densities of hogs, and concentrations of phosphate with densities of cattle, indicating that agricultural land use makes important contributions to nutrient loading in the Sumas in winter.

Fecal coliform counts were high during both wet and dry seasons, more than half the measures were above the guideline of 200 FCU/100 ml for recreational use of water or for irrigation of vegetables or fruit that is eaten raw (Figure 9). The 200 FCU/100 ml criterion applies to the geometric mean of at least 5 samples from the same location so that the more limited sampling done at each site in this study cannot be directly compared with the guidelines. However, the occurrence of so many high values in our samples points to a general problem of fecal coliform contamination in the Sumas River system.

Although the Sumas system has greater numbers of resident fishes than the Brunette and higher biomass, the fish community is still impoverished relative to nearby lowland streams with lower levels of

FIGURE 9
VALUES FOR SEDIMENT AND WATER QUALITY PARAMETERS IN THE SUMAS RIVER. BOXES ENCLOSE 50% OF OBSERVED VALUES, LINES SHOW RANGE OF OBSERVED VALUES, HORIZONTAL LINE WITHIN BOX IS MEDIAN VALUE. COPPER AND ZINC FROM SEDIMENTS, OTHER SUBSTANCES FROM WATER SAMPLES. NUTRIENTS AND COLIFORMS SHOWN FOR BOTH WET (NOVEMBER TO MARCH) AND DRY (APRIL TO OCTOBER) PERIODS.



contamination. This is not surprising given the poor conditions for fish life that we found in large parts of the watershed.

Overall, the Sumas watershed shows moderate to high levels of contamination by nutrients, heavy metals and fecal coliforms. Some of the heavy metal contamination is from natural sources, emphasizing the need to understand background levels and local geology in interpreting concentrations of any potential contaminant. However, a great deal of the contamination found in the Sumas derives from intensive agriculture. Intensive agriculture on a restricted land base creates an animal waste management problem. Disposal of farm wastes on an inadequate land base leads to nutrient and metal contamination of surface and ground waters, low dissolved oxygen and high ammonia in some surface waters, high fecal coliforms and generally degraded stream environments. These are problems well known to environmental

regulators but efforts to alleviate them have so far been unsuccessful. Environmental guidelines have been introduced for various producer groups as well as the Code of Agricultural Practice for Waste Management. Nevertheless, farms are operating with only about 60% of the recommended land base for environmentally sustainable waste disposal based on the standards and the code. Furthermore, current trends in land use suggest that conditions will get significantly worse in the future unless changes in land use and agricultural practice are instituted. Residential and industrial/commercial development is also occurring rapidly on slopes around the valley and this change in land use will greatly increase the contribution of urban non-point contamination to the system.

The Salmon River Watershed

The Salmon River Watershed occupies about 80.2 km^2 and is the largest of the three watersheds that we studied in detail. It is situated primarily in the Township of Langley. The Salmon River rises a few km east of Langley Township and cuts across its northeast corner, joining the Fraser River just west of the town of Fort Langley (Figure 3). The lower 10 km flows across an old meander channel of the Fraser River with gentle gradient and rolling terrain. At about km 5, Davidson Creek, one of the Salmon River's two main tributaries, enters from the east and drains the northeast quadrant of the watershed. Land use in the lower reaches is primarily agricultural except where the river skirts the southwest corner of Fort Langley. In the middle reaches (the next 20 km) the river is deeply incised into sand and gravel deposits of glacial-fluvial origin and has a narrow floodplain constrained by steep banks. The steep valley slopes and floodplain are well vegetated and the gradient is steeper. The river is a series of riffles and pools with gravel and cobble substrate. At about km 15 the Salmon is joined by its second main tributary, Coghlan Creek, which drains the east-central portion of the watershed. Land use in this central region of the watershed is a mixture of agriculture and low density residential. Williams Park, an important local recreation area, is situated at the confluence of the Salmon and Coghlan Creek. The central reach of the Salmon River cuts through the Hoppington aquifer, an important groundwater source. The headwaters (uppermost 10 km) flow through undulating terrain composed of glacial-marine deposits. The gradient is gentle and there is little streamside vegetation. The water is often stagnant during the summer. Predominant land uses are agriculture and low density residential.

The Salmon River watershed is relatively undeveloped with land uses consisting of 55% agriculture, 28% undeveloped, 8% residential and 9% other uses including parks and recreation. However, the watershed is at the edge of the rapidly expanding metropolitan area and is under considerable pressure for further residential development. The Salmon River is also an important coho salmon producing river, contributing about 5% of the coho salmon from tributaries downstream of Hope. Salmon persist in the Salmon River despite the fact that, like the Sumas, it is diked where it joins the Fraser and, when the Fraser is in flood, water from the Salmon is pumped across the dike. Many coho smolts migrating to sea are injured or killed when they pass through the pumps.

Our study of the Salmon River again emphasized stream sediment and water quality. Despite its relatively undeveloped watershed, previous studies of water quality in the Salmon had indicated elevated levels of NO3, phosphorus, manganese, iron and coliforms and occasionally high BOD and low oxygen concentrations. Both agriculture and domestic septic systems have been implicated as sources of contamination in the Salmon River. Our objectives were to compare trace metal concentrations in stream sediments with concentrations in surficial sediments from elsewhere in the watershed and to investigate further the sources of elevated nutrient concentrations in the river.

We analyzed sediments from 19 stations distributed throughout the Salmon River drainage network for 12 different trace metals. Metal concentrations were all higher than the world soil average except for nickel and lead, which were similar to the world average. Zinc, chromium, copper, cobalt, nickel, lead, manganese, and iron were all within the range of concentrations observed for Vancouver area stream sediments and zinc, chromium, copper and lead were also all within the reported range for uncontaminated sediments from the western US. Only zinc and lead were higher in Salmon River

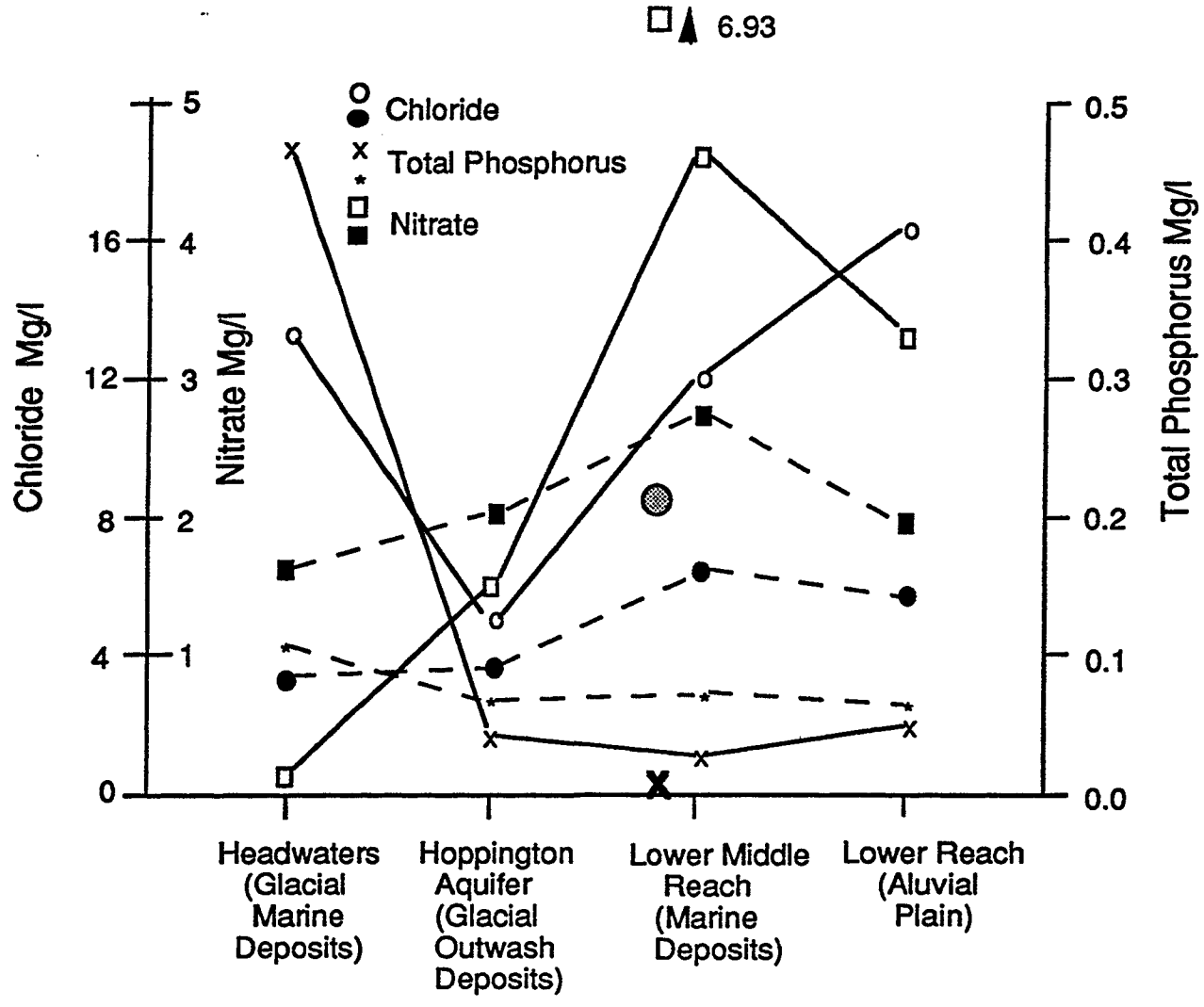
sediments than in the surrounding surface sediments of the watershed. The detection levels for lead were poor, however, so that further analysis of this contaminant is needed. Zinc was elevated only 1.4 times above background. Zinc tends to associate with fine particles of organic detritus so that the slightly elevated concentration of zinc in the stream could be explained by the higher organic content of stream sediments compared with samples from the adjacent land (stream sediments had about 4% organic carbon compared with 0.2 to 1.8% for terrestrial samples). Most metals were higher in concentration in sediment samples taken in summer compared with winter. Only a few of the differences were statistically significant, however, and most of the seasonal difference can probably be explained by seasonal changes in particle size distribution of the fine sediments to which the metal ions adhere.

In keeping with the relatively low concentrations of contaminants in stream sediments, concentrations of most contaminants were also low in the surface waters. However, there was a regional pattern to the concentration of various contaminants that provides insight into their origin (Figure 10). To compare contaminant concentrations we divided the river into the headwaters reach (the upper 10 km of river channel that cuts through glacial-marine deposits), the upper section of the middle reach above the confluence with Coghlan Creek (the section of the river incised into glacial outwash deposits containing the Hoppington aquifer), the lower section of the middle reach below the confluence with Coghlan Creek (where the channel cuts through predominantly marine deposits) and the lower reach (the lower 10 km of channel that cuts through the alluvial plain of the Fraser River). The middle section of the river was divided into above and below Coghlan Creek because this tributary has an important impact on the chemistry of the main Salmon River.

Chloride is an ion that occurs naturally in all surface waters but is also a potential indicator of pollution because it is present in contamination from many industrial operations, in road salt and in human sewage, among other sources. Natural surface waters in the region range up to 27 mg/l chloride. Measures in the Salmon River were generally less than 20 mg/l, however, there was a clear regional and seasonal variation (Figure 10). Values were low in winter, ranging between about 3 and 6 mg/l with slightly higher values in the lower two reaches compared with upstream. In the summer, during low flow, chloride levels were 2-3 times greater, ranging from about 5 to 17 mg/l. During summer, chloride was high in the upper reach, declined by more than half where the river cut through the Hoppington aquifer, was equal to the upper reach in the lower middle reach and continued to increase in the lower reach. Coghlan Creek had chloride values somewhat lower than the Salmon River at its confluence and probably served to dilute the concentrations in the main Salmon River somewhat. We speculate that the higher chloride values both upstream and downstream and in Coghlan Creek are due to anthropogenic sources of chloride such as human and animal wastes and inorganic fertilizers. However, the level of contamination does not appear to be serious.

Phosphorus is often the limiting nutrient for plant and algal growth in streams and rivers. We measured total phosphorus so the values are only an indicator of the bio-available phosphorus. Concentrations of phosphorus in surface waters typically range from 0.005 to 0.02 mg/l but may be higher when there is anthropogenic enrichment. There are no firm criteria for total phosphorus in river waters but criteria from various jurisdictions range 0.03 to 0.5 mg/l with most values below 0.1 mg/l. Elevated phosphorus in freshwater is a problem if it stimulates excessive plant growth (eutrophication) which can cause both aesthetic and ecological problems. Except for the headwater reach, total phosphorus values were generally below 0.1 mg/l and were somewhat higher in winter high flows than in summer low flows (Figure 10). As phosphorus is highly mobile, it tends to be carried quickly into stream channels from the adjacent land during rain storms. This, together with the greater demand for phosphorus by plants during the growing season probably accounts for the difference between winter and summer phosphorus concentrations in the lower three reaches. Phosphorus in the slow flowing headwater reach was very high during summer low flows. This is probably due to phosphorus becoming trapped in the stagnant pools during summer. Phosphorus concentration was low in Coghlan Creek. As with chloride, Coghlan Creek probably helped dilute phosphorus levels in the main Salmon River below its confluence. With the exception of the high values in the headwaters during summer and occasional high values seen in some tributaries, phosphorus concentrations throughout the watershed are well below 0.1 mg/l and do not seem

FIGURE 10
VARIATION IN THE CONCENTRATION OF CHLORIDE, PHOSPHORUS AND NITRATE FROM THE HEADWATERS TO THE MOUTH IN THE SALMON RIVER. OPEN SYMBOLS AND SOLID LINES SHOW SUMMER LOW FLOW VALUES AND CLOSED SYMBOLS WITH DASHED LINES SHOW WINTER VALUES. LARGE SYMBOLS TO THE LEFT OF THOSE SHOWING CONCENTRATIONS FOR LOWER MIDDLE REACH INDICATE MEASUREMENTS MADE NEAR THE MOUTH OF COGHLAN CREEK, WHICH JOINS THE SALMON AT THE START OF THIS REACH.



likely to be causing a serious eutrophication problem. Nevertheless, the River is experiencing anthropogenic enrichment of phosphorus that could lead to problems in the future if it increases. As the upper reaches of the Salmon are habitat for the threatened Salish sucker, poor water quality of the upstream reach may already be a cause of ecological problems.

Like phosphorus, NO_3 concentrations in the Salmon show both seasonal and spatial variability. In winter, NO_3 values were between about 1.5 and 3.0 mg/l, increasing from the headwaters to the lower

middle reach and then declining in the lower reach (Figure 10). During summer low flows, NO_3 values were very low in the slow flowing headwaters, increased dramatically downstream to values near 5 mg/l in the lower middle reach, then declined to about 3.5 mg/l in the lower reach. In the case of NO_3, Coghlan Creek contributed to high levels in the lower middle reach of the Salmon. The concentration of NO_3 in Coghlan Creek near its confluence with the Salmon was almost 7 mg/l, much higher than the concentration in the Salmon (Figure 10). During summer, NO_3 concentrations tended to be negatively correlated with discharge. This suggests that overland flow is relatively unimportant and that most NO_3 enrichment is coming from groundwater discharge into the system that is diluted by storm events.

The seasonal and spatial variation in NO_3 probably indicates the interaction of local enrichment with instream processes that use nitrogen. In the upper reaches, with high phosphorus availability, NO_3 may be the limiting nutrient for plant growth, leading to high phosphorus levels in the water but low NO_3. As the river passes through the glacial outwash deposits of the Hoppington aquifer and the marine deposits downstream it receives groundwater rich in nitrogen. Part way through this reach Coghlan Creek also contributes a high NO_3 load. At the same time, the stream channel is well shaded so that light limitation may reduce plant growth. High NO_3 and low phosphorus in the middle reach of the river suggests that, in summer, light and phosphorus limit plant growth so that excess nitrogen remains in solution. In the lower reach, riparian vegetation is greatly reduced so that light is abundant. Stream side agriculture probably contributes phosphorus to this reach so that phosphorus is less of a limitation on plant growth and nitrogen is stripped from the water by plants leading to a slight increase in phosphorus and a reduction in NO_3 in the water (Figure 10).

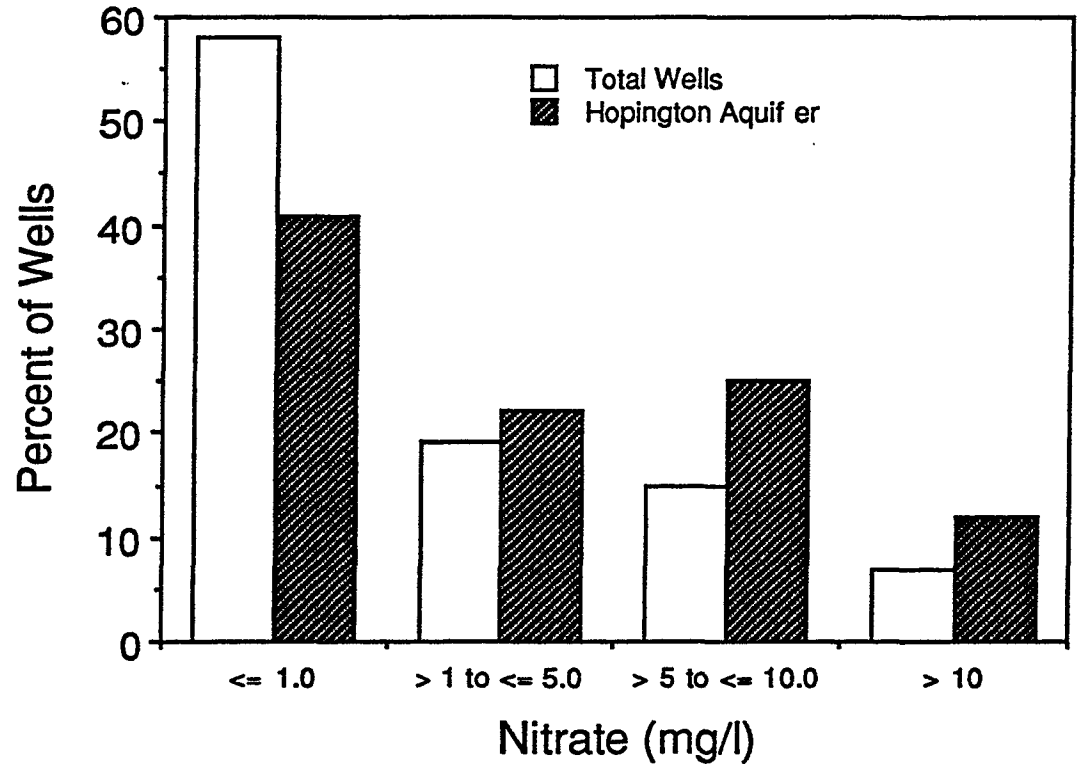
To explore further the impact of groundwater contamination and its sources on the Salmon River we analyzed well waters in the watershed. Virtually all domestic water in the watershed comes from wells and all domestic sewage is treated by residential septic tank systems. It has been known for some time that nitrogen levels are elevated in well waters from some parts of Langley Township. Natural levels of NO_3 in groundwaters for the region are believed to be in the range 1-3 mg/l. For the watershed as a whole, more than 30% of wells have NO_3 levels above background and about 7% are above the 10 mg/l standard for drinking water. Overall, about 22% of wells have NO_3 above 5 mg/l (Figure 11). Concentrations of nitrogen in groundwater are highest in the Hopington aquifer, with 48% of wells above 3 mg/l, 37% above 5 mg/l and 12% above 10 mg/l (Figure 11).

Groundwater is an important source of NO_3 to the Salmon River particularly during summer when base flows in the river are maintained by groundwater. A comparison of NO_3 concentrations in the river water with NO_3 concentrations in groundwater shows a strong association in the headwater and middle reaches of the drainage system. In the lower reach, however, NO_3 in the river remains high while NO_3 in groundwater drops to low concentration. High NO_3 in the lower reaches, therefore, must be a result of overland flow or contributions from further upstream.

A comparison of well water concentration of NO_3 with land use showed that NO_3 levels corresponded closely with intensity of residential development but less well with agricultural development. The same was true of land use activity and surface water NO_3 concentrations. However, both residential development (septic systems) and agriculture appear to be important contributors to the elevated NO_3 levels in groundwater and to the distinctive spatial variation in NO_3 concentrations in surface waters of the Salmon River drainage. Because of their permeability, glacial outwash materials appear to be the most sensitive to contamination from land use activities. In the Salmon River watershed, the greatest intensity of both residential and agricultural development occurs on these most sensitive soils.

The Salmon River watershed has experienced considerable alteration by human activities but remains a relatively pristine drainage system. The most obvious impacts of human activity on the aquatic system are increased loadings of nutrients to the surface and groundwaters. To date the increased nutrients have not

FIGURE 11
PERCENTAGE OF WELLS SAMPLED IN THE SALMON RIVER WATERSHED THAT HAD NITRATE LEVELS IN THE RANGES SHOWN. NOTE THAT WATER > 10 MG/L NITRATE IS NOT CONSIDERED SAFE FOR HUMAN CONSUMPTION.



caused a serious eutrophication problem in the river but NO_3 contamination in some well waters is above the threshold where human health problems are likely to occur. The primary sources of the excess NO_3 appear to be domestic septic systems and intensive agriculture (animal wastes).

Several important conclusions emerge from our study of the environmental health of the lower Fraser basin. First, while the environment remains moderately healthy, the pressure of human activity in the basin is pushing the environment to the brink of further ecological transformations. The kind of transformations that we foresee include even greater reductions in biological productivity, unmanageable degradation of water, soil and air quality, associated public health problems and loss of ecological integrity. Second, there are already serious local environmental problems that have cost society in lost ecosystem values, increased dependence on expensive technology, fewer lifestyle options, and increased public health risks. Third, the local environment is no longer capable of providing even the majority of ecological services of food and energy production and waste absorption necessary to sustain the local population. As a consequence, the local ecosystem is dependent on unsecured ecological services from elsewhere on the planet. There is no mechanism, national or international, for ensuring the integrity of this global commons in ecological services.

The Lower Fraser in The Global Environment

As is true of all densely populated regions of the globe, the lower Fraser basin is not self-sufficient in essential resources to sustain its present population. The regional ecosystem is heavily dependent on biological production, ecological services, and human generated goods and services from elsewhere to sustain the local population and its life-style. In considering the prospects for sustainability of the lower Fraser ecosystem it is important to have an estimate of the degree to which our ecosystem is dependent on other ecosystems and how secure is our tenure on the products of those other ecosystems. We have addressed the problem of our dependence on other ecosystems by calculating the additional land in various land-use categories that would be necessary to sustain the present population and life-style of the lower Fraser basin. We call this estimate the "ecological footprint" of the basin.

In making this estimate we employed 6 land use categories:

1. Waste Absorption Land. This is the land needed to absorb and assimilate the wastes of human activity. The principal component of these wastes is carbon dioxide produced by the burning of fossil fuels. We use and estimate of forested land required to assimilate wastes from fossil fuel consumption as a minimum estimate of the required waste absorption land.
2. Consumed Land. This is land irreversibly degraded as a result of urban and industrial construction. It constitutes the built environment of humans. Although this land is integral to our economy and lifestyle and is where most of us live, it provides virtually no ecological services.
3. Reversibly Built Land. This includes gardens, greenspaces, and other segments of urban development that are not irreversibly degraded. This land provides amenity services to humanity as well as some ecological services.
4. Crop Land. This is the land area needed to provide vegetable and other green plant crops for human consumption.
5. Pasture Land. This is the land needed to provide animal protein for human consumption.
6. Managed Forests. This is the forest land needed to provide wood fiber and lumber for human consumption.

To estimate the land required in each land use category we used five major categories of human consumption: food, housing, transportation, consumer goods, and services. Per capita consumption in these categories can be calculated from regional or national data. The land area required to satisfy per capita consumption in the various categories is determined by dividing per capita consumption by the average productivity of the land use that generates the good in question. In many instances, the consumable good in question is derived from more than one land use category. In these instances we had to estimate the separate contribution of each land use category to production of the good. For example, food comes primarily from crop and pasture land. However, some land is also required to absorb carbon dioxide from fossil fuels used in food production, forest land is required to provide packaging, and some food is produced in urban gardens. These different land use categories were all taken into account in estimating the land base required for food production. The end result of this analysis shows how much land in each category is required to support the consumption of a single individual. Based on our analysis, the average Canadian (which we assume is representative of the lower Fraser basin) requires about 4.27 ha of land summed over the various land use categories to provide for his or her present material standard of living (Table 1).

We can use these statistics in a variety of ways. For example, they can be used to calculate the area of land in the various categories needed to sustain the present population of the lower Fraser basin. These estimates can be compared with the amount of land in the various categories that is actually present in the basin to estimate a "land deficit" for the ecosystem. Conversely, we can use the present land base of the lower Fraser basin to estimate the sustainable population size for the basin.

In Table 2, the land needed to support the 1991 population of almost 1.8 million was calculated from the values for an average Canadian. For example, the area of land for waste assimilation is 2.34 ha/person

times 1,780,000 persons = 41652 km^2. Crop and pasture land, separate land uses in Table 1, were combined for the calculations in Table 2 and consumed and reversibly built land were combined into urban land. In total, the population of the lower Fraser basin has an ecological footprint of 76006 km^2. Since the settled area of the lower Fraser basin is only 3090 km^2, this means that the regional ecosystem

TABLE 1
AREA OF LAND (HA) REQUIRED BY THE AVERAGE CANADIAN IN EACH OF 6 LAND USE CATEGORIES TO PROVIDE FOOD, HOUSING, TRANSPORTATION AND CONSUMER GOODS AND SERVICES.

LAND USE	CATEGORY OF CONSUMPTION					
	Food	Housing	Transportation	Consumer Goods	Services	Total
Waste Absorption	0.33	0.41	0.79	0.52	0.29	2.34
Consumed Land		0.08	0.10	0.01	0.01	0.20
Reversibly Built Land	0.02					0.02
Crop Land	0.60			0.06		0.66
Pasture Land	0.33			0.13		0.46
Forest Land	0.02	0.40		0.17		0.59
Total	1.30	0.89	0.89	0.89	0.30	**4.27**

TABLE 2
LAND AREA (KM^2) AVAILABLE IN THE LOWER FRASER BASIN AND NEEDED TO SUPPORT THE PRESENT POPULATION. DEFICIT IN LAND IS THE DIFFERENCE BETWEEN LAND AVAILABLE AND LAND NEEDED. POPULATION THAT COULD BE SUPPORTED BY THE BASIN IS FOUND BY DIVIDING THE LAND AVAILABLE IN EACH CATEGORY BY THE LAND REQUIRED BY THE AVERAGE CANADIAN IN THAT CATEGORY FROM TABLE 1.

LAND USE	Land Available in the Lower Fraser Basin	Land Needed to Support the 1991 Population of 1,780,000	Deficit in Land Base for the Lower Fraser Basin	Population That Could Be Supported By The Existing Land Base
Crop and Pasture	950	19936	18986	84821
Forest	1140	10502	9362	193220
Urban	1000	3916	2916	454545
Waste Assimilation	Negligible	41652	41652	Negligible
Total	3090	76006	72916	72365

has a "land deficit" of 72916 km^2. Put another way, the ecological footprint of the population of the lower Fraser basin is almost 25 times the land area of the Fraser Valley. These figures may appear surprising but they are by no means unusual for urbanized regions of the industrial world. They serve to emphasize both the absolute dependence of our population and life-style on land resources outside our community and national borders (and, therefore, outside our direct control) and the extent of the impacts (largely unseen by us) of our population and life-style on distant ecosystems. As another way of

considering the issue of sustainability in relation to the regional ecosystem we can ask how large a population could be supported by only the ecological productivity and processes within the Fraser Valley. Agricultural land and waste absorption land are the limiting factors and, overall, the region is capable of supporting only a little over 70,000 people.

The land deficit of the lower Fraser is made up by other lands distributed all over the globe, wherever goods and services that contribute to our way of life are produced. It is not practical to imagine exercising regional or even national control over it. However, at present the need to secure these services for our population is not even a consideration in the planning of national and international environmental strategies. Yet, if we are to achieve anything approaching sustainability, satisfying this land deficit must be a part of the process. Of particular importance is the requirement of our society for natural capital to support our economy. Natural capital is all the resources, both renewable and non-renewable, that provide the raw materials for our economy. A number of these resources, particularly air, water and soil, are not substitutable in the economic sense. They are essential to the continued existence of humankind on earth. But at present they are accorded no value in our economy. They are exploited in a global commons and there is no mechanism in that commons to protect their quantity or quality.

Social Change and Social Health

Although global issues, like the ecological footprint and the land deficit of the lower Fraser basin, have not received the attention they deserve in the growing human concern over environmental quality, a great many legislative and institutional changes have been implemented to address problems of environmental quality. Environmental regulation has become much more pervasive in recent years, spurred by high levels of public concern for the environment, particularly in the 1970's and early 1980's. Yet the majority of human activity remains outside the ambit of environmental regulation. For example, there are more than 85,000 business, government and NGO organizations in the lower Fraser basin. Only about 100 of these are regulated in terms of any discharges they may make to the environment. Others discharge to the domestic sewer system or diffusely into the atmosphere or onto land. We conducted a survey of more than 4000 firms to assess their attitudes toward environmental management. The survey revealed that most firms think they have little impact on the environment. Many firms have, nevertheless, adopted some practices to minimize or manage their production of wastes. Of 316 firms that responded to our questionnaire, 261 had some kind of environmental management practice and most had multiple practices. The most common practice was recycling, either connected with municipal recycling programs or internal recycling of by-products from production. However, 166 respondents also had hazardous waste disposal plans, 135 had emergency response programs and 120 had environmental training for staff (Table 3). This latter statistic is important because a common complaint in the environmental literature is that companies are willing to have environmental policies but not to spend money on training. Most firms also reported that they had developed their environmental programs in response to environmental regulations.

Not surprisingly, the number of environmental practices that firms adopt is related to their size. Larger and more visible firms tend to have the greatest environmental impact and, therefore, come under greater scrutiny. We found that 76% of large firms (> 100 employees) had 5 or more environmental practices but only 46% of medium sized firms (11-100 employees) and 22% of small firms (10 or fewer employees).

As a particular case, we examined water quality management in the lower Fraser basin. An elaborate regulatory framework exists for water quality management involving federal, provincial and local levels of government. Federally, the departments of Fisheries and Oceans and Environment have the strongest mandates to address water quality issues while provincially it is the Ministry of Environment, Lands and Parks. Local governments have only delegated authority but this can be substantial. In the lower Fraser basin, the Greater Vancouver Regional District is a key player, having responsibility for both liquid and solid waste management for the district. So far, aboriginal governments have played relatively little role. But, with the continuing devolution of powers to First Nations governments, their authority and

responsibility for water quality management will increase in the future. Interacting with the large number of government agencies involved are non-governmental organizations of various sorts (e.g. environmental groups, industrial organizations) and the firms themselves.

TABLE 3
FREQUENCY OF VARIOUS ENVIRONMENTAL PRACTICES BY 316 FIRMS IN THE LOWER FRASER THAT RESPONDED TO A QUESTIONNAIRE.

ENVIRONMENTAL PRACTICE	FIRMS	ENVIRONMENTAL PRACTICE	FIRMS
Recycling Program	261	Community Relationships Program	63
Energy Savings Program	183	Environmental Policy Declaration	62
Hazardous Waste Disposal Plan	163	Environmental Packaging	60
Emergency Response Plan	135	Contributions to Environmental NGO's	60
Company-wide Environmental Policy	124	Environmental Choice Labeling	56
Environmental Training	120	Environmental Impact Assessment	53
Environmental Communications	118	Product Stewardship	49
Pollution Prevention Program	105	Separate Environment Department	42
Environmental Management System	92	Environmental Accounting	42
Environmental Site Assessment	91	Total Quality Environmental Program	38
Environmental Audit	76	Lifecycle Analysis	36
Environmental Code of Ethics	75	Environmental Marketing	32
Environmental Officer	73	Environmental Recognition Awards	23
External Environmental Reporting	70		

The large number of actors in the water management field has led to a loosely coupled system with extensive linkages both vertically and horizontally. We examined 54 organizations involved in water quality management in the lower Fraser and found that these organizations had established 781 linkages among themselves and with other organizations. Furthermore, more than 60% of these linkages were used on a regular basis. The loose coupling within this complex institutional/organizational field is consistent with (and may have helped create) the discretionary and conciliatory approach to environmental regulation and management that is characteristic of Canadian environmental management. Since the early 1970's, bargaining has been the essence of the environmental regulatory process in Canada. Until recently, environmental policy decisions were made primarily in closed door meetings between government officials and industry. In the past few years, however, the bargaining process has expanded into a multi-stakeholder negotiation. Increasingly, affected parties are resorting to the courts to help resolve complex issues. This is forcing a more open, adversarial system of decision making.

Although the loose coupling within the organizational field for water quality management has allowed solutions tailor made to particular problems it has also tended to discourage localized markets for pollution control. Most firms in the lower Fraser are not engaged in the kinds of market transfers that often characterize more advanced approaches to environmentalism. Most are not part of regional associations dedicated to creating and implementing pollution programs. Nor are they involved in coordinated pollution abatement programs with local governments. There is, as yet, no market for the trading of pollution permits and most firms have not formulated long term positions on environmental control.

The pulp and paper industry is the exception to this rule of loosely coupled governance. Four of BC's 26 pulp and paper mills are within the lower Fraser basin and more are located upstream on the Fraser and its tributaries. Because of extreme public concern about toxic substances in pulp mill effluents (specifically, dioxins and furans) this industry has been regulated as stringently as any industry anywhere in the world. The result has been a virtual elimination of dioxins and furans from pulp effluent but not the complete elimination of toxic pollution problems associated with pulp mills. The regulation of pulp mill effluents in BC is an example of a tightly coupled governance system.

The pulp and paper industry appears to have engendered a strongly coupled governance system for several reasons including the fact that individual firms are large and obvious structures, the public is well informed about the potential of pulp mills to pollute, and there are good, authoritative data on the character and toxicity of mill effluents. It is, thus, a relatively easy matter for regulatory institutions to focus attention on pulp mills. By contrast, diffuse, non-point pollution from urban run-off is generated by a myriad of human activities, has no clearly defined source and is poorly understood scientifically. As a consequence, there is no well defined institutional process for regulating urban run-off and little inclination by regulatory agencies to tackle the problem. The kinds of social and institutional obstacles to pollution regulation illustrated by urban run-off means there is often little connection between the degree of regulation and the impact of particular kinds of human activities on ambient water quality.

Although firms and the institutional structures that regulate commercial behaviour are an important component of the social aspect of sustainability, by far the most important components are demographic structure and demographic change. Historic patterns of population growth and social change were touched on earlier. The present patterns of demographic change are dramatic and important to any prospects for sustainability in the lower Fraser. In the mid 1980's the slowing of population growth nationally prompted a change in immigration policy. Targets for overall immigration were set much higher and programs deliberately aimed at attracting entrepreneurs and investors were implemented. British Columbia has been a destination of choice for a large fraction of the greatly increased flow of international immigrants while retaining its place as the province that attracts most internal migrants within Canada. Demographic change in the lower Fraser is driven primarily by patterns of immigration and emigration as birth rates are relatively low and have been below replacement for several decades. Nevertheless, net immigration has been large and overall growth in population substantial.

The city of Vancouver has not been the main recipient of the growth. Although Vancouver's population grew by 14% between 1981 and 1991, the inner suburbs grew much more. Richmond added 32% to its population while West Vancouver grew 39%. The greatest proportionate increase, however, was in the outlying communities. For example, Abbotsford/Matsqui grew 60% during the decade, Surrey grew 67% and Pitt Meadows grew almost 80%.

We have analyzed recent changes in the population of the lower Fraser basin in terms of three distinct flows of people, migrants within the province of BC, migration to and from other provinces of Canada, and international migration. These migrations seem to be driven primarily by the attractiveness of the economy of the lower Fraser relative to elsewhere in BC, elsewhere in Canada, and internationally. When the resource economy of interior BC declines, interior residents migrate to the metropolitan area in search of work. When BC has a strong economy relative to the rest of Canada the lower Fraser attracts immigrants (primarily from Alberta and Ontario) but, at the same time, emigration to other regions of the province also increases. There is, thus, an inverse relationship between within province migration to the lower Fraser and immigration from other provinces. Notwithstanding these important migrations within Canada, the greatest factor in social and demographic change in the lower Fraser in recent years has been international migration. In 1993, about 45,000 international immigrants arrived in BC and in 1994 about 50,000, between 70 and 75% of whom settled in the lower Fraser basin.

The flow of immigrants is steadily altering the ethnic composition of the region. More than 80% of Canadian immigrants now come from Asian countries. In the metropolitan area in 1991, 167,000 residents gave their ancestry as Chinese, second only to the 365,000 who gave British ancestry. Asians other than Chinese are less abundant but represent a rapidly growing fraction of the population. International immigration to the region in recent years has been more than 70% of Asian origin. What is happening in the lower Fraser is by no means unique in Canada or in other developed countries, however, it is part of the ongoing restructuring of the post-colonial world.

We anticipate that population growth and ethnic change will continue into the future. To explore the impact of continuing demographic change we made three projections of population 30 years into the

future based on optimistic, pessimistic and average assumptions about economic growth and immigration policy. These projections predict a population between 3 and 4 million for the lower Fraser by the year 2030. If current trends continue, the ethnic face of the population will look much different in the future than it does today.

Diversification is evident in the changing socio-cultural makeup of the population. As it has in the past, ethnic diversification is generating a good deal of racial tension. Stereotyping and the linking of certain ethnic groups to particular kinds of crime or "asocial" behaviour decrease support for the present immigration policies and multiculturalism. The economic benefits linked to immigration are countered by the high public costs of extra services such as training in English as a Second Language (ESL). Student enrollment in ESL training has jumped dramatically in the past few years and some school districts, for example Vancouver (with 48% ESL students) and Richmond (with 39%), have very high percentages of such students.

While the ethnic character of the region has been changing so has its economic character. By the end of the 1970's Vancouver had become a "post-industrial" city with its government and styles of development reflecting the values of professionals, managers and other kinds of specialists. The growth of the service economy has occurred throughout the basin with the service sector itself becoming more differentiated. Finance, insurance and real estate have experienced a 300% increase in the last 3 decades while accommodation and food services increased 400%. By 1991, service sector jobs represented almost 76% of all employment. By contrast, changes in employment in the goods manufacturing sector were small. There is evidence of a redistribution of manufacturing jobs out of the congested metropolitan core to urbanizing suburbs. As population continues to grow over the next few decades, jobs in the goods manufacturing sector will increase. However, we expect that the jobs will be concentrated in fewer firms and will constitute a declining proportion of overall employment.

In commenting on the nature of employment in the service economy, the Economic Council of Canada noted that the jobs fell into two distinct groups: highly skilled, well compensated and stable jobs and relatively unskilled jobs with low wages and low security. The Council concluded that the growth of service sector employment meant that the labour market was offering economic security to fewer and fewer Canadians. The kind of economic disparity that the Economic Council highlighted is easy to document in the lower Fraser basin. For example, median family income in West Vancouver, an affluent municipality, was more than $77,000 whereas in Vancouver it was only about $40,000. Growing income disparity, and decreasing personal economic security when coupled with rapidly changing ethnicity seems likely to accentuate social conflict in the region.

The kinds of tensions engendered by the demographic and economic changes sketched above are well illustrated in the agricultural sector. The lower Fraser basin contains almost 1/3 of all farms in BC and employs more people in agriculture than any other region of the province. Agriculture is important economically and provides the basis for a distinctive and socially valued way of life. Tension and conflict over the competing claims of farming and urban development and efforts to defend the rural way of life are a constant thread through the history of the area. But they have seldom been as acute as they are at present. In BC, prime agricultural land is protected from development as part of the Agricultural Land Reserve. However, the Reserve has failed to protect prime farm land on the fringes of urban areas where the pressure for residential and commercial development is intense. Between 1983 and 1992, 1327 ha of agricultural land was lost in the lower Fraser basin. This loss of farm land coupled with the increasingly competitive character of agriculture has led to great intensification of agricultural activity. The use of machinery, agricultural chemicals and fertilizers all increased dramatically in recent years. Industrial farming in which animals and other crops are raised entirely indoors in climate controlled barns or greenhouses is becoming the norm. As was the case with the development of forestry, capital and even part of the labour for farming comes from outside the region. These absentee capitalists have no particular stake or interest in the landscapes or rural lifestyles of the lower Fraser and are concerned with the environment only in-so-far as it affects their return on investment.

Overlain on these dramatic changes in population, ethnicity and economic character of the basin are equally dramatic changes in the relationship between the colonial and aboriginal communities of Canada. These latter changes are likely to have as profound effect on future development and resource use in the region as population growth itself. The community of immigrants has occupied the lower Fraser basin for less than 200 years. In that short time the immigrant community has overwhelmed and transformed the ecology and economy of the basin. By contrast, the aboriginal community has lived in the basin for thousands of years. Throughout that long period of residence, their technology and economy appear never to have exceeded the assimilative and regenerative capacity of the landscape or the ecosystem. Their numbers were never large in the past and are still small. The residential communities of the aboriginal peoples sit almost unobserved and generally ignored amid the bustling and expanding metropolitan area and the factory-farms of the immigrant community. Yet the aboriginal community has interests in the lower Fraser that, arguably, outweigh those of all others combined. Although the exact nature of their role in decisions about the future of the Valley has yet to be fully defined, the importance of that role cannot be denied. It rests on a growing legal and political recognition of aboriginal rights and aboriginal title.

The recognition of aboriginal rights and aboriginal title has set in motion negotiations to define the property rights that aboriginal residents of the lower Fraser basin have to the lands, waterways and resources that their ancestors occupied and used for hundreds of generations. The strength and breadth of the aboriginal peoples' bargaining position has been established by a number of court decisions about the character of aboriginal rights. Although those decisions have clearly recognized the existence of aboriginal rights in general, they have left ambiguous what those rights mean and much remains to be negotiated. For example, recent court decisions about aboriginal fishing rights in the lower Fraser have affirmed an aboriginal right to fish but denied a right to sell those fish. An important feature of recent judgments is their concern with how aboriginal rights are based in the specific socio-cultural system of each aboriginal people. The rights of the Sto:lo peoples of the lower Fraser basin, for example, are rooted in the continuing reality of Sto:lo culture and are specific to that culture. This means that rights that the Sto:lo derive from their culture and traditions may not apply to other First Nations and vice versa. Specific attributes of rights and title will have to be worked out separately for each cultural grouping.

In the preliminaries of negotiation, the Sto:lo have claimed title to all the lands and resources of the lower Fraser basin. Although it is not possible to say what precisely will be demanded at the negotiating table, other recently negotiated treaties in Canada provide some guidelines. It seems likely that the Sto:lo claim will include more direct ownership of existing reserves, ownership of additional lands, compensation for lands and resources presently owned and used by others, guarantees of exclusive use of some resources and participation as owners in decisions about future development that may impinge on lands and resources that are part of their traditional culture. That is to say, the Sto:lo will claim an interest in and a right to a meaningful say in virtually every decision regarding land and resource use in the lower Fraser basin.

Formal negotiation of their claim has yet to begin but the Sto:lo have already begun the process of exercising their rights and enlarging their sphere of political influence. They have reclaimed control of a range of social services that had been administered by the federal government and are also taking control of development activities on reserve lands. Under the Aboriginal Fisheries Strategy they have regained the right to administer their own fishing activities in the lower Fraser River. It seems likely that this incremental process of increasing aboriginal authority over a range of aspects of land and resource use will continue into the future. There is also the prospect of a fairly dramatic redefinition of the policy and decision making process for land and resource use should land claim negotiations conclude successfully. Whether or not treaties are concluded, the Sto:lo are asserting their right to be recognized as a separate and legitimate order of government.

From the perspective of our study it is important to ask what the emergence of a Sto:lo government and greater Sto:lo involvement in land and resource use decisions will mean for sustainable development in the lower Fraser basin. It is not possible to offer a firm answer to this question. For generations, the

Sto:lo lived without dramatically affecting the structure and function of the lower Fraser basin ecosystem. It seems doubtful that this was deliberate. Rather, it was a consequence of the constraints imposed by their technology and their dependence on local stocks of resources. The evolution of their economy and their society is no longer constrained in this way. Recent decisions by aboriginal communities about development on reserves suggests that they are prepared to accept ecosystem transformation in return for economic benefits. On the other hand, the aboriginal peoples of the region have a very strong attachment to place. This attachment is likely to affect the overall pattern of development decisions by aboriginal communities in ways that are not easy to predict. Finally, whatever the pattern of land and resource use aboriginal communities might like to see, what is feasible will be constrained and modified by the realities of the large and growing immigrant economy of the region and the global economic interdependencies of all communities regardless of culture.

Sustainability of the Present Ecosystem

Extrapolating current trends into the future does not yield an encouraging picture in terms of sustainability. Environmental degradation and environmental pollution is high in some parts of the lower Fraser and is increasing. The rate of population growth in the basin is easily capable of overwhelming our historically slow response to problems of waste management and infrastructure development. For example, our estimates indicate that within 10 to 15 years population growth alone will cancel any benefits of the secondary sewage treatment that is presently being installed. Schools, roads and public transit are likewise inadequate for the present and projected population of the region. The private automobile is and will continue to be the primary means of individual transportation with attendant waste of fossil fuels and generation of atmospheric contamination and greenhouse gases. Landfills continue to be the most common means of disposing of solid waste and landfills are an important source of methane and CO_2, both of which contribute to global warming. The Burns Bog landfill in Delta, which receives the majority of metropolitan Vancouver's solid waste, produces about 3% of the total methane from landfills in Canada. Overall, due to human effects on the carbon cycle, residents of the lower Fraser basin contribute to greenhouse gas accumulation in the atmosphere at rates above the national average. Expansion of urban land use and intensification of agricultural land use are transforming the ecology of large areas of the lower Fraser and degrading other areas. An important consequence of these changes is reduced biological productivity of the region so that the capacity of the region to support human activity is declining at the same time as human demands are increasing. Economic activity and life styles of basin residents are becoming increasingly dependent on inputs from other parts of the globe. The ethnic character of the basin is changing rapidly with immigration and, at the same time, aboriginal peoples are beginning to exercise their political authority. As a consequence the human community of the basin is experiencing significant shifts in the economic and political power structure with attendant social unrest. The present configuration of the basin ecosystem is not sustainable and present patterns of change are moving the ecosystem further and further from sustainable options.

What kind of an ecosystem do we want to have a generation from now?

Introduction

Change in the lower Fraser basin is inevitable. It remains to be seen whether we will find ways to manage the change so as to move toward configurations that are more sustainable. Present trends in the lower Fraser indicate that we are moving away from sustainability. Managing change to achieve a more sustainable ecosystem implies that you know what you want. The question, "What kind of an ecosystem do we want to have?" was perhaps the most contentious of our four guiding questions. Some investigators argued that this was not a question that we should address at all. Others were equally adamant that we were morally bound to use our professional training and knowledge to publicize the precarious state of the basin and advocate more sustainable ways of living. Still others felt that our responsibility was primarily to help members of the community discover their own futures, whatever they

may be. It seems unlikely that there is any single and certainly no final answer to this question for the communities of the lower Fraser basin. Nevertheless, the question is a crucial one and if we do not decide it for ourselves, it will be decided for us by default. We have explored this question for the lower Fraser basin in three ways, by an analysis of official community plans, by poling basin residents, and by analysis of resident's perception of environmental risks and threats.

Analysis of Official Community Plans and other Regional Planning Documents

The various communities within the lower Fraser basin have undertaken a number of planning exercises. Examples include the Official Community Plans prepared by individual communities and municipalities within the lower Fraser basin (e.g. the City of Port Moody Official Community Plan adopted in 1992), Official Settlement Plans prepared by regional district governments for all or parts of regional districts outside municipalities (e.g. the Official Settlement Plan for Popkum-Bridal Falls adopted by the Fraser-Cheam Regional District in 1984), problem specific plans (e.g. Clouds of Change. Final report of the City of Vancouver Task Force on Atmospheric Change, 1990), and institution specific plans (e.g. A Living Working River: A management plan for the Fraser River Estuary by the Fraser River Estuary Management Program). Each of these documents constitutes a statement of objectives and strategies for land use, development and human activities within the community or geographic area of concern. All of the planning exercises involved extensive public consultation and review. Thus, the plans represent a broad consensus within the communities about what is desired and how to achieve it. The plans are a rich source of information on what the residents of the lower Fraser basin value and what directions they want development to proceed.

We reviewed a total of 55 plans. Twenty-five of these were Official Community Plans and twenty-nine were regional or issue specific plans. Only one, the Fraser Estuary Management Plan, was institution specific. Most of the plans were very recent or had been recently updated (since 1990) but some dated back to the late 1970's. The plans are not binding on local governments but once they are adopted councils are constrained from passing by-laws or undertaking projects that are at variance with the plan. A number of the plans are more than a decade old but still have not been formally adopted by local Councils even though they have been serving to guide community development during that period. By not formally adopting a plan, Councils may be seeking to avoid being constrained by its objectives.

At the regional level, only the Greater Vancouver Regional District (GVRD) has developed a comprehensive set of plans. However, the GVRD's Livable Region Strategy includes objectives for districts east of the GVRD in the Fraser lowland. Analysis of community plans for the lower Fraser basin shows a clear dichotomy of preferences between communities inside and outside the metropolitan region. Communities outside the metropolitan areas have a strong desire to preserve their rural character whereas communities inside the metropolitan region see their future in terms of greater urbanization. The Livable Regions Strategy attempts to accommodate this dichotomy of values.

The Livable Region Strategy together with the Fraser Estuary Management Plan and three companion documents (The green zone strategy, Transport 2021, The air quality management plan) provide a statement of regional objectives for land and river management in the western half of the lower Fraser basin. The overall objective is to accommodate the present and anticipated population growth without jeopardizing highly valued aspects of the living environment, landscapes, viewscapes and ready access to natural areas. The plan opposes the recent pattern of sprawling residential development expanding south and east up the valley. It proposes to replace this pattern of development with greater densification in the western and northern areas where urbanization has already transformed the landscape. Tactics for achieving these broad objectives include delineating and protecting an extensive green zone, building complete and compact communities, making the metropolitan region itself more compact, and increasing the range of transportation choices.

In the context of this plan, complete communities are those with a full range of services and amenities, a range of choices in transportation and housing and a match between jobs and residents. Compact

communities have high density residential areas with people close to services, employment and recreation. By a compact metropolitan region, the plan means a continuous urbanized area centred on a main downtown core (Vancouver) but having a number of independent municipal town centres with no sprawl into the green zone or onto Fraser Valley farmland. The town centres and the core would be connected to each other and with their surrounding communities by an efficient system of rapid transit. Each community would have a job/labour force ratio that approaches 1:1, a diversity of housing types and costs and all necessary services. Under the plan, Vancouver, Burnaby, New Westminster, North Surrey, North Delta and the northeast sector of the region are slated for higher growth and densification whereas Richmond, the Langleys, the south region and the Fraser Valley regions of the GVRD would have lower growth than at present.

The Green Zone Strategy begins by identifying land to be protected from urban development. By establishing an extensive and connected Green Zone, the Green Zone strategy complements the objectives of compactness and densification in urban development. Land available for urban development is constrained thereby forcing greater densification and more compact development. Lands included in the Green Zone fall into four categories:

1. Community Health Lands (watershed for domestic water supply, lands prone to flooding or seismic damage, and lands that provide a buffer against natural and man-made hazards);
2. Ecologically Important Lands (lands that are needed to maintain ecosystem integrity, preserve genetic diversity and contribute to awareness and understanding of natural processes);
3. Recreational and Scenic Lands (parks, playgrounds); and
4. Renewable Resource Lands (agricultural land, aquaculture land and forest land).

Transport 2021, the regional transportation plan was a joint project of the province and the GVRD with input from the federal government and other regional districts. The principal objective of the plan is to reduce dependence on automobiles by providing a greater range of choices. Associated objectives are to develop the transportation system in support of the compact metropolitan region objective and to minimize the impact of transportation systems on the quality of the environment.

As it is in most metropolitan regions, air quality is a persistent and growing problem within the lower Fraser basin. The Air Quality Management Plan proposes to reduce and minimize the effects of poor air quality on public health and the environment by minimizing emissions. Central to a meaningful reduction in emissions is a reduction in private automobile traffic. The goals of the Air Quality Management Plan are, therefore, highly dependent on other aspects of the Livable Regions Strategy; achieving compact and complete communities and developing alternate modes of transportation.

The Fraser Estuary Management Plan articulates a complementary set of objectives for lands and waters seaward of the protective dikes. Originally created to coordinate and streamline the review and approval process for shoreside development, the Fraser Estuary Management Program has become an important planning body for port and foreshore development. The Estuary Management Plan has three broad goals: 1) To ensure that environmental quality and habitats within the estuary are sufficient to sustain healthy fish, wildlife, plants and humans; 2) To enhance the estuary's role as the social, cultural, recreational and economic heart of the region; and 3) To encourage human activities and economic development that protects and enhances the environmental quality of the estuary. In accordance with the Livable Regions Strategy, the Estuary Management Plan proposes to concentrate development according to the compact communities objective and to have industrial development concentrated within defined "industrial cores". Future development of estuary lands is delineated in the context of Transportation 2021.

An important feature of these plans is their integration and complementation. The plans are mutually supportive and mutually dependent. Together they seek to satisfy a range of environmental, social and economic objectives within the context of continued population growth and economic transformation of the region. There is a strong emphasis on preserving and enhancing the quality of both urban and rural environments. The planners recognized that institutional and jurisdictional fragmentation is the enemy of the broad objectives of the plans and emphasize the need for partnerships and cooperation in

implementing the plans. Finally the plans emphasize the importance of public support and continued public involvement as the plans are implemented and results begin to emerge.

Individual community plans generally put forward similar broad goals; encourage economic growth and diversification, protect environmental resources and satisfy the social needs of the people. Above all, the residents of the individual communities want to retain the present character of their community and to create a sense of stability and place. This desire translates into a greater willingness on the part of urban communities to absorb population growth provided it is concentrated in appropriate areas and adequate open space is preserved. Rural communities are less comfortable with growth. They want to ensure that what growth does occur is concentrated around regional town centres and along transportation corridors so that the majority of the land base is left relatively undeveloped. Most plans call for development patterns and other measures that reduce dependence on automobile transportation. As one means to make automobiles less attractive, some plans call for fewer parking lots and no new arterial routes. Most communities want to maintain or increase the amount of land for industrial development but also want to concentrate this development in specific areas and encourage industries that provide a diversity of jobs. Rural communities in particular see tourism as a means to increase economic opportunities without sacrificing their goal of maintaining a lot of open and green space within the community.

Rural communities are also concerned that farm land should be protected, agriculture encouraged and open space for both passive and active recreation maintained or increased. The concern for agricultural land is not confined to rural communities, however, and there is strong support among the community plans for the Agricultural Land Reserve. Some communities also encourage the consolidation of small agricultural parcels into economically viable farming units. Farm lands are seen not only as a distinctive aspect of the community but also as an aspect of environmental quality. Many plans also call for protecting other important features of the natural landscape such as old growth forests, wetlands, wildlife habitat and fish bearing streams.

Overall the community and regional plans place great emphasis on protecting the environment, maintaining the quality of life and sustaining the unique character of individual communities throughout the lower Fraser basin. Economic growth is encouraged but not at the expense of the environment or social objectives. Population growth is seen as inevitable and all the communities seek to minimize its environmental impacts by containing residential growth and encouraging complete communities with a minimum of commuting to work. The plans are broadly consistent with what is needed to redirect human activities toward a more sustainable relationship with the natural environment of the lower Fraser basin. Based on our analysis of the present state of the environment of the basin and recent trends in development, however, it appears that the lofty goals of the plans are not being realized. The question remains as to whether the plans truly represent the desires of people living in the lower Fraser and to what extent those desires can be realized when they oppose powerful interests.

Polling the Attitudes of Lower Fraser Basin Residents

To assess further public attitudes toward the environment and other issues, in July 1995 we conducted a telephone survey of 1638 residents of BC, mostly in the lower Fraser basin. In addition to the random sample, we deliberately oversampled 100 additional respondents in each of the Punjabi and Cantonese ethnic groups and the residents of Abbotsford. The oversampling was intended to ensure statistically reliable samples from two ethnic groups that have comprised a large percentage of recent immigrants to the lower Fraser and from one of the rural communities outside the main metropolitan area. The results of the survey provided important insights into those aspects of environmental quality about which residents were most concerned. The survey also allowed us to determine how individual concerns were related to such things as age, education, ethnic background, and where the person lived, and in which activities related to the environment and environmental protection people participated.

Concern about environmental problems ranked second behind unemployment in the minds of respondents to our survey. In general, the rank order of concerns was similar in the lower mainland compared with

the rest of the province, with the top 4 issues (unemployment, environment, taxation and the deficit) accounting for more than 60% of responses. When given a choice between protecting the environment or protecting jobs, a strong majority favoured protecting the environment. However, a strong majority also felt that economic growth was more important than environmental protection. Despite their opposition to taxes, a majority (58%) of respondents in the lower mainland felt that government should do more to protect the environment even if it meant higher taxes. A strong majority (>65%) of respondents was slightly to very concerned about the quality of the environment in their local area and an equally strong majority (75%) felt that people were severely abusing the environment. Almost 78% of respondents agreed with the statement that when people interfere with nature it often produces disastrous consequences and more than 88% believed that people must live in harmony with nature in order to survive. Although there are some contradictions and conflicts in people's attitudes toward the environment, overall the responses indicate a concern for the environment and a belief that society as a whole must do more to protect the environment and adapt to limitations imposed by the environment.

For the lower mainland, motor vehicle exhausts and air pollution were the most important environmental problems (32% and 15% respectively) whereas elsewhere in BC logging and groundwater contamination were most important (18% and 14% respectively). There was a stronger consensus on the most important problems among residents of the lower mainland (the top 4 problems mentioned by 65% of respondents) than elsewhere (the top four problems mentioned by 50% of respondents).

Several questions indicated how residents of the lower Fraser viewed the implications of their environmental concern for other aspects of life. For example, 66% agreed that residents of BC will have to reduce their level of consumption drastically for the sake of environment, while 69% agreed that there should be tougher anti-pollution laws even if such laws decreased the standard of living. A slight majority (50.5%) agreed with the statement that population growth is undermining quality of life in my area, however a much higher percentage (75%) agreed that people are severely abusing the environment. Respondents were divided on the statement that the size of BC population must be limited even if it means less economic development (42% agree, 45% disagree).

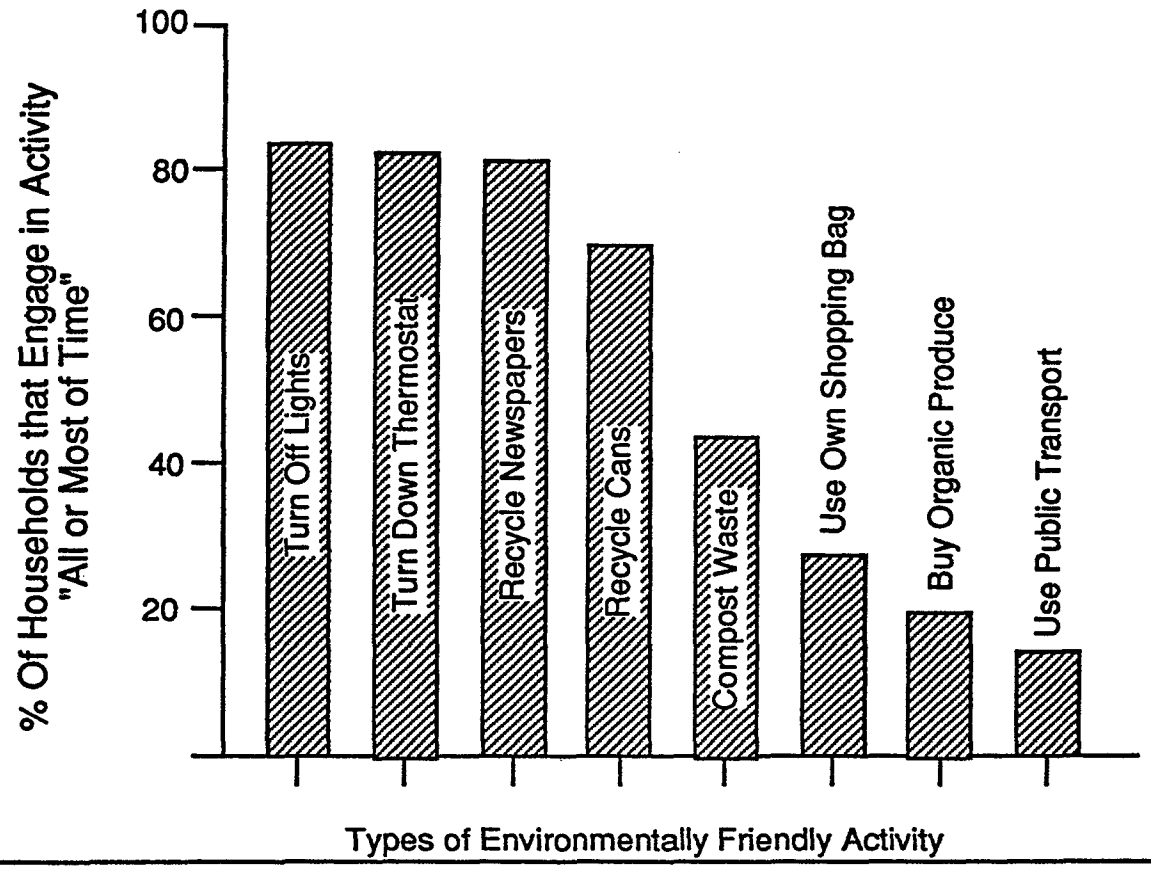
When we examined the strength of environmental concern in relation to education we found that more highly educated individuals showed higher levels of environmental concern on global issues but not on local issues. The sex of the respondent was much more strongly related to environmental concern with women showing significantly greater degree of environmental concern than men. Age was also related to environmental concern. The youngest respondents scored higher than the oldest, but those with the greatest level of concern were in the middle age group. This was a somewhat surprising result but we speculate that this group represents individuals established in the community and raising families. Thus, we may expect their concern with the quality of the environment to be high. Among the various groupings of respondents, individuals with Asian background showed lower levels of environmental concern than other groups. Although the trends outlined above were clearly evident in the data, neither demographic characteristics, political nor religious affiliation had much explanatory power. By far the majority of the variation in environmental attitudes among individuals had nothing to do with age, sex, ethnic origin, level of education, or any other characteristic that we measured.

When asked questions about how best to address environmental problems, respondent's answers were sometimes contradictory. For example, a strong majority disagreed with the proposition that environmental protection was more important than individual land owner's rights. However, equally strong majorities agreed with the propositions that, to prevent destruction of natural resources, government must have the right to control private land use and that people do not have the right to modify the natural environment to suit their needs. A strong majority of respondents believed that tougher anti-pollution laws were needed (>65%), that governments would have to control industrial growth (>63%), that government should protect the environment without all the red tape (75%), that more regulation of business was needed to protect environment (>63%), and that stiffer penalties were needed for companies that pollute (86%). However, a majority of respondents also felt that economic growth was more important than environmental protection (>59%), that individuals have primary responsibility to protect

environment (~50%), and that communities grow best through private decisions by individuals who know their own needs (~50%). Respondents placed a high priority on giving people more say in local decisions (56-62%).

People's strong belief in the importance of individual action did translate into some environmentally friendly forms of consumer behaviour, especially those that produce financial dividends to the individual, such as turning off lights when leaving the room (84%) and turning down the thermostat at night (83%). Many fewer respondents engaged in activities that were costly of individual time or money, or those that might expose them to public conflict. For example, among the environmentally friendly activities offered, respondents used public transit least (14%), yet this is the activity with the greatest benefit to the environment. Participation as an office holder in environmental organizations or in environmental protests were also activities in which few respondents engaged (Figure 12).

FIGURE 12.
PERCENTAGE OF TIME THAT RESPONDENTS ENGAGED IN PARTICULAR KINDS OF ENVIRONMENTALLY FRIENDLY ACTIVITIES "IN THE HOUSEHOLD".



Our results suggest that environmental attitudes and environmental behaviour are connected but not very strongly in some instances. Concern for the environment was significantly correlated with environmentally friendly consumerism, with environmental activism and with an index of an individual's willingness to pay for environmental protection. Environmental consumerism was also associated with an individual's attitude toward populism but had no relationship with the individual's position on the left or right of the political spectrum. As noted earlier, women were more concerned about the environment than men but, even taking this difference into account, men were less likely to engage in environmentally

friendly consumerism. This may relate to such things as the greater likelihood of women to shop for the household and to use public transport than men. Some correlates of environmental consumerism may relate to opportunity. For example, residents of the lower Fraser were more likely to engage in environmental consumerism than other residents of BC and those who live in houses scored higher than those who live in apartments. These higher scores may relate to the greater access to recycling programs in the greater Vancouver area and to the fact that municipal recycling programs have tended to target house owners more than apartment dwellers.

In contrast to environmental consumerism, the probability of engaging in environmental activism decreasing from left to right on the political scale. Residents of Asian origin were also significantly less likely to engage in environmental activism than other residents. Two forces are probably at work here. First, British Columbian's of Asian background tend to show lower overall concern for environmental issues and also tend to be more conservative in their values. Second, many residents of Asian origin had immigrated to the region within the past 10 years. Recent arrivals may be less familiar with and less likely to use more radical methods of influencing public opinion.

The willingness of respondents to pay for environmental protection included such things as willingness to incur job losses, settle for a lower standard of living, pay more for gasoline and accept higher utility prices. Willingness to pay was, in fact, more closely correlated with measures of environmental attitude than either environmental consumerism or environmental activism. Willingness to pay was positively associated with level of environmental concern and knowledge but negatively associated with conservative attitudes and Asian origin.

We attempted to obtain information on the attitudes of First Nations on environmental issues and desires for the future from a separate interview process. The interviews themselves were open ended and opportunistic. Not all issues were covered in each interview and sometimes the interviews were with individuals and at other times with groups of native Canadians. Although the information that we obtained was not sufficient for a detailed analysis of First Nations attitudes, it did identify some important viewpoints that will have to be taken into account in future policies for environmental management in the lower Fraser basin.

The number of native Canadians resident in the lower Fraser basin is not known for certain. The majority (about 60%) live on the 98 reserve areas in the region. In 1989 the total population on the Indian Register of the federal Department of Indian and Northern Affairs (DINA) was just over 5000. If one includes the off-reserve population then the total native Canadian population of the region was on the order of 8000 in 1989. First Nations communities are growing rapidly in numbers, however, and we can expect the aboriginal population to double over the next 30 years. These figures are not accepted by many First Nations administrations, as they do not agree with DINA's criteria for defining a status Indian. Whatever criteria are used to identify native Canadians, the number is small relative to the total population of the region. As pointed out earlier, however, the First Nation's will have an impact on future development of the basin that far outweighs their numbers.

The land area occupied by reserves is also relatively small, about 10,800 ha. However, First Nations are engaged in comprehensive land claims negotiations with the federal and provincial governments and their land claims include all of the lower Fraser basin. First Nations fully expect, and the position of both federal and provincial governments in negotiations is consistent with this, that resolution of land claims issues will include recognition of their status as a separate order of government. Consistent with federal policy, the Department of Indian and Northern Affairs (DINA) has begun to devolve authority and responsibility for many community services and land management to individual bands. Through negotiation, through the courts and, sometimes, through civil disobedience, First Nations have begun claiming a right to a much stronger say in resource development and resource management decision that affect them.

First Nations are very concerned that, during this time of negotiation, development within the basin should not jeopardize either their way of life or their future opportunities. Interviewees expressed the belief that aboriginal rights to property and management responsibility are entrenched rights. They also stated that First Nations have the right to live in a non-urban environment. Because of their commitment to place they also have a commitment to a healthy river and sustainable environment. Some interviewees expressed a need for action on the condition of the river which they believe is no longer clean and healthy. In this context they believe that First Nations have the right to a say in how the river and valley are managed including the right to veto development proposals that jeopardize their way of living.

To support their belief that the water is no longer clean, interviewees offered several observations. Places in the lower Fraser where they collected agates as children formerly had clean water but now had cloudy water and the rocks on the bottom were covered with silt. Fishing rocks near Spences Bridge upstream were black now rather than gray. They believed this was due to pollution. Formerly eels (lamprey) could be harvested at several sites in the river but haven't been seen for years.

Rights regarding fish and fishing are paramount to lower Fraser First Nations because of the profound importance of fish in their culture. One chief mentioned that his community name means "red fish in the river" and that there were sockeye in their rivers at one time. Another said that they fish in the river and that the fish are their territory. Restrictions on opportunities to fish are a hardship because everyone wants to go and fish. Nevertheless, one interviewee commented that they had given up two of their allotted five days of fishing that year because the number of returning fish was low.

Problems with the salmon resource are of particular concern to First Nations. Some interviewees were upset and confused as to why there was no First Nations representation on the Fraser River Sockeye Public Review Board that was set up to look into the problem of missing fish. Others expressed the view that today, the economic, cultural and spiritual values of fish have been separated whereas in the past these were unified. First Nations have become aliens in their traditional family fishing sites as fishery resources have become part of international economy. First Nations have been excluded from decision making and resources have been given to third parties.

Water rights on reserves is an unresolved issue. Provincial policy gives allocation precedence to users in relation to the time at which they first began to use water resources. The fact that they were resident in the area and using water prior to colonization suggests a priority right of native Canadians to water. However, licenses for water use by aboriginal peoples were not recorded until after white settlers had appropriated most of the water.

Environmental concerns are not the only concerns of First Nations, nor even necessarily their greatest concerns. Interviewees also expressed a need for jobs and economic development on reserves. They also expressed a strong desire for a resurrection of traditional ways and the teaching of their language to First Nation's children. Some reserves have set aside land to be excluded from development. However, when asked specifically about protection for animals the response was that, although they loved animals, they had to look out for people first, for families and a good future for their people. People came first.

The desire for economic development on reserves and more jobs for First Nations members has led to conflicts with other communities over environmental regulation. Provincial regulations do not extend onto reserves and federal regulations are seldom enforced. First Nations have not yet fully developed their own policies and by-laws governing environmental management. An example of conflicts that was mentioned in our interviews was a proposal to construct a garbage incinerator on reserve lands that had to be shelved because of opposition from nearby communities off the reserve.

In summary, analysis of the polling results and interviews with native Canadians shows that the environment is important and that public opinion is skewed, but not dramatically skewed, in a "concerned" direction. Concern about the environment cuts across key social divisions. The poorest and least educated residents are as likely as the richest and best educated to care about environmental problems

both locally and globally. Native Canadians are also concerned with the environment but their concerns may centre on different issues and reflect a different way of connecting with place than is common for other residents.

Women are significantly more concerned than men, a phenomenon that appears nearly universal in western democratic societies. However, in contrast to other studies of environmental attitudes, the middle aged in the lower Fraser are more concerned than any other age group. Political affiliation is also linked with environmental attitudes and reflects the strength of the environmental agenda of the different political parties. NDP and Green Party supporters have higher levels of environmental concern than supporters of other parties.

Distinguishing between local as opposed to global environmental concern helped identified factors with potential policy relevance. For example, residents of Asian origin were no different from other residents in their concern over local issues but were less likely to be concerned about more abstract global issues or to ascribe to the tenets of environmentalism in general. Overall, socioeconomic, ethnic and partisan differences explained rather little of the variation in opinion among respondents. Environmental attitudes were, however, important predictors of environmental consumerism, activism and willingness to pay for environmental protection. This suggests that, to the extent that education and information raise awareness of environmental issues, behaviour will change toward patterns that are more environmentally friendly.

The Perception of Environmental Risks

At this point in our analysis it appears that a substantial majority of residents of the lower Fraser basin desire an ecosystem in which natural environmental amenities are maintained, particularly those relating to the pastoral landscape of the valley and the ready access to rugged wilderness on the mountain slopes. Clean air and clean water are also high on the list of environmental priorities. These are not unusual or radical desires in a modern industrial society. They are important elements in a high quality of life and they are elements threatened by continued population growth and urban expansion in the lower Fraser basin. However, it may be that future policies are dictated as much by what people don't want, by what they fear or by what gives them a great sense of loss, as much as by what they want. We, therefore, undertook to explore what residents of the lower Fraser perceived to be important risks to the environment and water resources in particular.

Managing risks to human health and safety has become a dominant theme in government policy and public debate. An important feature of governance of public health risks has been the degree to which human perception of risks has influenced decision-making. Research in this area has adapted psychometric scaling methods to characterize people's perceptions of the relative riskiness of various technologies. Although in recent years threats to the health and integrity of ecosystems has also become a topic of considerable public concern, there have been few attempts to characterize public perception of that risk and the kinds of human activities perceived to be risky. In our project we adapted procedures developed for the assessment of public perception of human health risks to assess public perceptions of threats to the ecosystem.

The approach was first to develop a set of items perceived to be threats to the natural environment and a set of scales reflecting characteristics of the items that may influence a person's judgment of risk. For example, items include such things as population growth, loss of animal species, and acid rain. Scales include such measures as certainty of impact, number of people affected, and reversibility. A sample of the public completed a questionnaire in which they rated each of the items on each of the scales. The results provided insight into people's perceptions of the ecological risk associated with various human activities and technologies and also identified important dimensions of the human perception of ecological risk. The study was performed twice, once to explore ecological risks in general and a second time to look more specifically at risk to water and related resources.

In the study of general ecological risks, 65 items ranging from nuclear war to scuba diving were rated. Those considered to pose relatively little risk included outdoor recreation, scuba diving, fireplaces, tourism, and golf courses. Items considered to pose a great risk to the environment were nuclear war, loss of animal and plant species, ozone depletion, and habitat loss. There was a high degree of cross-correlation among the 31 scales used to judge riskiness, indicating that individuals tended to rate items at the same level of riskiness on many scales. Twenty-four of 30 individual scales of risk had correlations of more than 0.5 with a scale of overall riskiness and more than half the correlations were greater than 0.8. However, four scales that measured human capacity to manage risk (avoidability, controllability, ability to regulate, availability of alternatives) had low correlations with the scale of overall riskiness (correlations ranging from 0.11 to 0.22). This is in contrast to studies of perceived risks to human health and safety in which human control over an item is typically highly correlated with overall riskiness.

Factor analysis of the results identified five dimensions that explained 91% of the variability in the data (the first two factors alone explained 74%). The first dimension measured impacts on non-human species and involved primarily such items as loss of species, animal and plant suffering, and overall destructiveness and reversibility of effects. The second dimension measured benefits to society and involved primarily benefits to society and individuals. The third dimension also had a human focus but measured adverse impacts on humans and involved such measures as the number of individual affected, relevance to life and scope of the impacts. The remaining two dimensions captured only a small amount of the variance in perceived risk; the 4th dimension involved controllability of impacts and the 5th knowledge of impacts. The first three factors were highly correlated with individuals' assessments of the overall riskiness of various items.

Analysis of the 65 items along the five dimensions revealed some interesting contradictions. Items having the greatest impact on species included loss of wetlands, loss of plants and animals, and loss of habitat in general. All of these items scored considerably higher than nuclear war and climate change, both of which would be expected to have devastating effects on species over large geographic areas. In addition, some natural hazards, such as flooding and draught, were considered to have very little effect on species. Automobiles were ranked as having high social benefits but also high impacts on humans, which may reflect the growing ambivalence in society toward the automobile. Cigarettes were ranked as having the least benefits to society but did not show up as an item having high impacts on humans. Population growth and technology were considered to have high impacts on humans and to be relatively unavoidable. However, neither item showed up as contributing to impacts on species. Big business, which is frequently vilified for its impact on the environment, did not show up as having a serious impact on species but was rated as an item about which there was little knowledge of impacts.

The perceived trade-off between societal benefits and ecological benefits can be examined by comparing item scores on the first two dimensions. Items considered to have little impact on species but high societal benefits were outdoor recreation, travel in general, and the automobile. Items considered to have low societal benefits and low species impacts included most natural hazards, cigarette smoking and use of aerosol cans. Items considered to have both high species impacts and high societal benefits are those most likely to provoke conflict and require compromise, These included such items as housing development, dams, intensive farming and economic development. In this comparison big business also showed up as having relatively high societal benefits and species impacts.

The second study employed a similar method to explore public perception of risks to water and related resources. The sample population was structured to allow comparison between residents in different parts of the lower Fraser basin and between expert and lay opinions. Thirty-three items were scored on 17 scales by members of the public from 3 communities of the Fraser valley and a sample of students from the University of BC. In addition, 16 individuals who work as professionals in aquatic science and management were asked to score the items on two scales; general riskiness and need to regulate.

Comparison of overall scores for the items among the different communities revealed only two significant differences. Residents from the three residential communities rated the items as more relevant to their

lives and as posing slightly more risk to human health than did the sample of university students. On the specific scales of general risk and need to regulate, there were some minor differences between communities but overall the similarity among samples indicated uniformity of perception throughout the lower Fraser basin. As with the study of general risk perception, there was a high degree of correlation among the scales of risk measurement. Factor analysis of the results revealed 4 dimensions that explained 90% of the variance. Dimension 1, which explained 50% of the variance, was a combination of dimensions 1 and 3 from the previous analysis (impacts on non-human species and on humans) whereas dimensions 2-4 were related to societal benefits, controllability of impacts and knowledge of impacts, as in the earlier analysis. The results of this analysis, therefore, closely paralleled those of the earlier study.

When considered in terms of the first two dimensions of the factor analysis, items that were perceived as having little impact on species (both human and non-human) but high societal benefits included paddle boating, sport fishing and selective logging. Items perceived as having high species impact but little societal benefit included UV radiation, acid rain and liquid waste. Items with high impact on species but high societal benefits, thus requiring trade-off decisions, included population growth, urban development, auto emissions and water chlorination. As in the study of general ecological risks, population growth was considered to be relatively uncontrollable.

On the overall scale of risks, acid rain, automobile emissions, UV radiation due to ozone depletion, disposal of liquid waste in sewers and climate change were all perceived to pose very high risks to the aquatic environment. There were some important differences in the way experts and lay persons rated risk. For example, experts rated logging roads, introduction of species, population growth, sport fishing and urban development as significantly higher in risk than the lay sample whereas the experts rated acid rain, acid rock drainage from mining, drought, flooding, UV radiation and leachates from landfills as significantly less risky than the lay sample. On the question of need to regulate there were also areas of agreement and disagreement between the expert and lay samples. Both groups recognized a need for strict regulation of most items. However, experts rated hydro-electric dams, construction of logging roads and species introductions as more in need of regulation than did the lay people. Experts also rated acid rain, automobile emissions, and motor boating as less in need of regulation than the lay people.

The two scales, general riskiness and need to regulate, were both highly correlated with the four dimensions of risk perception. General riskiness was most strongly correlated with impacts on species followed by societal benefits and knowledge of impacts. General riskiness was not correlated with the controllability dimension. In contrast, need to regulate was highly correlated with the controllability dimension. Thus, there was a strong correspondence between the most important dimensions of risk and perception of the need to regulate, but the need to regulate was most closely tied to what people perceived could be regulated.

While the results of these analyses do not suggest any specific policy of environmental management they provide important insights into how members of the public perceive risks, what they perceive to be risky, and how their perceptions may be changed by various kinds of information. People's perceptions of risk are influenced by their assessment of the benefits associated with an activity. Thus, the greater the benefits to humans or society as a whole, the lower is the risk perceived to be. For example, in the study of risks to aquatic resources, people rated chlorinated water as having both a high impact on species but also high societal benefits. This conflict probably contributed to a relatively low overall rating of risk for chlorination (25th out of 33 items). The relationship between the public's perception of controllability and need to regulate is also important. If lack of knowledge or other factors lead the public to believe that a particular hazard is not controllable, there may be a general complacency about the hazard even if its impact is quite serious and it is controllable. Knowing the dimensions of environmental risk perception will also help with both the design of environmental policies that will be meaningful to the public and in identifying the factors that should be emphasized in any program to change public behaviour.

What is feasible for us to accomplish?

Defining the kind of ecosystem that we would like to have tends to have utopian overtones. Many conflicts and contradictions are conveniently glossed over. As we have seen above, what people want is not always what they do, perceptions about the risks of human interactions with the environment do not always conform to the facts and there are many factors over which we believe we have little control. What we will be able to achieve as a society will depend greatly on what is feasible given present circumstances. Unfortunately, the definition of feasibility is almost as elusive as the definition of what we want. However, our research suggests five important dimensions to feasibility that must be taken into account in designing policies to move society toward sustainability.

Geography

Local geography has a profound influence on what is feasible in terms of the environment, economy and society. The fact that our ecosystem straddles the mouth of a great river with excellent harbours has greatly affected and continues to affect the patterns of development in the lower Fraser basin. That the local ecosystem is separated from the provincial hinterland by rugged mountains and that the river did not provide easy access through the mountains forced early settlers to look north and south along the coast for communication routes, transportation and resources. These same factors today help keep our attention on the Pacific and Asia as a natural sphere of economic activity rather than eastward to the rest of Canada and the Atlantic coast. Its mild maritime climate and the dramatic setting help make the lower Fraser a desirable place to live while the limited flat valley bottom land and rugged surrounding terrain contribute to land use conflicts and transportation problems. Policies for sustainable development in the lower Fraser must be consistent with the constraints and opportunities offered by local geography.

History of Economic and Social Development

Past patterns of economic and social development create a structure of institutions and regulations that are not easily abandoned. The fact that BC's water resources legislation has not been amended to address such pressing problems as groundwater contamination, the need to monitor and review licensed water uses, and to protect flows to maintain ecological integrity of streams, testifies to the tenacity of historic institutions. Even when appropriate policies are adopted, historic institutional constraints may conspire to prevent their implementation. For example, both local and provincial transportation policy for the lower Fraser advocates a transition to more environmentally sustainable modes of transportation, reduced use of the private automobile, greater use of public transit, bicycles, and walking. The technology and the plans exist to implement this policy but recent transportation projects do not seem to reflect either the policy or the plans. In part, this is because the engineering expertise in municipal works departments invariably translates the policy into the things they were trained to do, such as building more roads and bridges. In part, it is because our social and physical infrastructure has been built around the assumption that the individual private vehicle will be the primary mode of transportation. The public works planners and engineers are bound to respond to this dominant feature of our society. People strongly resist giving up the perceived freedom and flexibility of their individual automobiles. Yet, reducing road traffic would be the single most effective measure to curb non-point sources of pollution in the lower Fraser ecosystem. To be feasible, policies for change must take account of this inertia in the system.

Government Quest for Revenue

As we noted above, an overriding imperative of governments is the quest for revenues. Without a reliable source of revenue, governments cannot guarantee services. And a government that cannot guarantee basic services will not long remain in office. Thus, governments are unlikely to pursue policies that would significantly reduce revenues. In BC, a primary source of government revenues has been the liquidation of resource stocks. Depletion of natural capital to generate revenue is attractive to governments because the benefits can be realized now and the costs will not have to be paid until long into the future, by some other government. Liquidation of forests in the valley was an illustration of this.

Policies that shelter resources from various forms of development, such as the provincial policy to increase park lands and the agricultural land reserve, are always contentious even if they have a relatively minor effect on government revenues. Even if such courageous policies are enacted, their validity is likely to be continually challenged in ways that do affect government revenues. For example, governments may be castigated for loss of potential tax revenues and developers may threaten to withdraw capital investment. The Agricultural Land Reserve is a good example of legislation that is continually challenged in these ways. To be feasible, policies for change must minimize any negative consequences for government revenues.

The Disconnection between Human Actions and their Consequences for the Environment

As the lower Fraser has become increasingly connected to the global economy and as the proportion of urban dwellers dependent on technological support systems has grown, the disconnection between individual and societal actions and their environmental consequences has increased. The individual drinking coffee in an urban cafe has no tangible connection with the deforestation of tropical hillsides to grow coffee. Nor does this individual have any tangible connection with the domestic agricultural system that may have produced the food on the cafe menu and the leather in her shoes and pocket book, or with the forest harvesting system that produced the paper for the newspaper she is reading. Indeed, most of us have no direct connection with the majority of environmental impacts associated with our life styles. In fact, we have worked very hard to ensure that we experience as little as possible of the environmental and social consequences of the majority of our choices as consumers. This makes it very difficult to enact policies that would reduce many kinds of environmental degradation, especially if such policies affect aspects of our lives that are tangible, like the year round availability of cheap fresh fruit and vegetables, the municipal tax rate or the price of gasoline. Policies to encourage more sustainable configurations of the environment, economy and society must take account of this disconnection between actions and consequences.

Our Fiduciary Responsibility to First Nations

As was noted earlier, a factor of growing importance to what is feasible in terms of the environment, economy and society in Canada is the recognition of native Canadian rights. First Nations are taking on the responsibilities and authority of a 4th order of government. The full extent of the powers that they will have and the manner in which they will exercise authority depend on the outcome of treaty and land claims negotiations. Nevertheless, it is apparent that native Canadians will have an influence over development patterns that is disproportionate to their numbers into the foreseeable future. Any attempt to define sustainable configurations of environment, economy and society for the lower Fraser will have to include First Nations as a full partner.

Global Imperatives

Our work on the ecological footprint of the lower Fraser ecosystem emphasizes that economic, social and environmental forces outside the lower Fraser are having a growing influence on what is feasible locally. The dependence of lower Fraser communities on goods and services from elsewhere and the declining capacity of the regional ecosystem to provide the essentials of life narrows our options and undermines the independence of our communities. The lower Fraser basin is part of a global ecosystem and policies to manage locally will not be feasible if they run counter to global imperatives. At the same time, our very dependence on forces outside our ecosystem presents an obstacle to sustainable development locally.

How (in terms of new policies and instruments) can we accomplish what we want?

The importance of national and global forces notwithstanding, the lower Fraser basin ecosystem is the region over which we have the greatest influence in terms of policies and programs that would sustain not only desired environmental attributes but also important social and economic structures. Although it may not be sufficient, it is here that we must begin the task of living in a sustainable way. In our research on

policy and the instruments of social change, therefore, we concentrated our attention locally. We initiated two projects specifically related to policy development and implementation. The first was development of an interactive tool for exploring the implications of policy choices. This took the form of a computer based game in which decision makers choose options for the future on a range of policy dimensions, discover the implications of those options, and can then interact with the game to explore trade-offs and configurations that yield more or less satisfactory results. The second was to work directly with government agencies or intergovernmental committees to incorporate information and principles from our study directly into regional policy and programs. In the latter approach our objectives were twofold; first to facilitate the incorporation of information and ideas into the political and bureaucratic decision making process and second to determine how and under what circumstances more sustainable kinds of policies could be implemented.

The Policy Scenario Analysis Game

A wide range of economic, social and environmental factors must be considered in evaluating the sustainability of any ecosystem configuration. Furthermore, there are many possible sustainable configurations for an ecosystem and many ways to work toward such a configuration. A common problem that decision makers face is how to determine whether a particular policy or set of policies will move the system toward some desired and, hopefully, more sustainable configuration. There are few objective tools that the decision maker can use to explore the consequences of policy decisions. We designed a game, the Quasi-Understandable Ecosystem Scenario Tool (QUEST), specifically to help decision makers explore how policy choices might affect the sustainability of the lower Fraser ecosystem.

The model is structured in the form of an interactive game. Although it is intended primarily as a tool for decision makers, any interested person can play the game. The player first chooses a set of policies to guide development from among a suite of options in 9 important policy areas: transportation, housing, lifestyles, agriculture, government spending, industrial development, water supply, labour and land use. The options within each area are intended to represent aspects of life in the lower Fraser basin over which elected officials can expect to have some control. For example, under transportation the player can specify priorities for different kinds of transportation (private automobile, public transit, walking, biking), vehicle occupancy, fuel efficiency and permissible emission levels; under lifestyles the player can specify such aspects as health awareness, energy and water consumption, goods consumption and waste management; and under government the player can specify revenues, whether or not a deficit will be allowed, and spending on a range of public and social services.

Once the policies are established, the game assumes full implementation of the policies by the year 2030 and calculates how the particular suite of policies would influence society, the economy and environment in terms of a set of output variables and indicator variables. Output variables are typically numeric whereas the indicator variables are typically presented graphically against time. The model includes 12 categories of output (population, land use, transportation, economic performance, water quality, air quality, ecological footprint, housing, energy use, labour, social services, and wildlife habitat) with a range of measures in each category. The player has access to 52 indicators that can be quickly plotted to show patterns and trends in such things as population size and distribution, land use patterns, various aspects of transportation and lifestyles, patterns of consumption and pollution, level of public health, and the ecological footprint for the region.

By playing the game a decision maker can quickly gain an appreciation for how different combinations of policies affect broad aspects of environment, society and economy in the lower Fraser basin. The game makes it obvious how policy decisions intended to affect one area of human activity spill over to affect other areas, often with undesired consequences. Although the patterns of environment, economy and society that emerge from different policy combinations are important and revealing, more important still is the requirement for trade-offs and compromise that the interaction of policies makes explicit.

The game has only recently become an operating tool but is already generating considerable interest not only locally but internationally. The Greater Vancouver Regional District has provided additional funding to tailor the game to help it address some particular regional problems. Our intent was not to use the game to prescribe policies. However, we have explored a number of scenarios while evaluating the usefulness of the game and these have pointed to some major regional issues. For example, without major changes in the policies governing land use and transportation in the Fraser valley we run a high risk of loosing about 1000 km^2 of agricultural land over the next 30 years to urban development. This represents a very high percentage of the remaining agricultural land in the basin. With continued reliance on the private automobile as our principal mode of transportation, local air quality problems will triple in severity with attendant public health implications. Policies in the model that increase housing density and decrease automobile use can result in a saving of 750 km^2 of agricultural land and, by 2030, air quality could be better than it was in 1990. By providing these kinds of outputs, the model highlights in a very visual way the hard choices that we have to consider, the benefits of making certain choices and the costs of failing to address the choices.

Implementing Sustainability at the Community Level

During the project we worked with a number of local communities and government regulatory bodies to provide information that underscores the need for action now, to educate decision makers about the broad regional and global implications of local decisions, and to assist individuals, managers and decision makers to find more sustainable solutions to traditional problems of social and economic development.

With the City of Richmond we began with the concept that a healthy and sustainable community requires the co-occurrence of a resilient and productive environment, a viable economy and a socially self-sustaining population. The concept of a healthy community was rooted in the WHO definition of health as a resource that gives people the ability to manage, change or adapt to their surroundings. Using this definition, the concept of health is useful in articulating how individuals are nested within communities and communities within an ecosystem, and how the well being of one affects the well being of the others. The way a community is organized has implications inward for the health of individual citizens and outward for the health of the ecosystem of which the community is a part and on which it depends.

Defining the interrelationships between the community and the ecosystem forced us and the representatives of Richmond to come to grips with the limits of the environment. Whatever technology we employ, the community cannot be sustained if the ecological processes on which it depends are continually degraded. We used the concepts of appropriated carrying capacity and ecological footprint to show how decisions made within the community have broad impacts on other communities and on the regional and global ecosystem. The issue of consumption was central to these discussions. Levels of material consumption that cannot be replenished by the ecosystem in which the community is imbedded are unsustainable. Our analysis of individual and collective levels of consumption and its implications for the environment has shown that community consumption patterns are well above anything that can be considered sustainable. The City of Richmond had come to a similar conclusion and had adopted award winning approaches to sustainability at the community level. However, the city lacked an effective tool for assessing the ecological consequences of policies designed to restrain consumption and a meaningful alternative to ever higher material consumption as a measure of community well-being.

The heuristic tool of the ecological footprint proved very useful in comparing the ecological implications of municipal by-laws. By analyzing policy alternatives and proposed by-laws in terms of their implications for the ecological footprint of the city, Richmond could explore the trade-offs between environment and economy more objectively. Richmond is presently developing an environmental check-list for analyzing by-law proposals so that the ecological considerations can be more easily factored into municipal decision making. However, policies that greatly reduce individual consumption will not be palatable unless there is a meaningful and acceptable alternative against which people can judge

community well being. What is needed is a socially acceptable alternative to material consumption as a symbol of quality of life.

To assist with identifying such an alternative, we developed the concept of Social Caring Capacity (SCC) as the social complement to the ecological concepts of the footprint and appropriated carrying capacity. SCC is a policy filter through which decision makers can identify and explore the potential social consequences of any action taken to decrease aggregate consumption. The heart of SCC is a set of rules for pre- and post-analysis of policy decisions that forms an adaptive feedback loop for managing and controlling change. To be effective the community must be intimately involved in this process. But when applied in concert with footprint analysis, the SCC provides insights not only into the social consequences of policy options but ways to mitigate or ameliorate any negative effects of reduced consumption.

SCC is still in the preliminary stages of development as a working policy analysis tool. However, it is already evident that SCC can do much more than show how to make the best of a bad situation. SCC can be a means to enhance the quality of life within a community at the same time as consumption rates fall. This is accomplished by searching for policies that promote and strengthen the social networks that enhance the quality of life but that also reduce aggregate consumption.

With the Township of Langley we provided an initial stimulus for the formation of a federal-provincial-municipal partnership to implement sustainable watershed management for the Salmon River. Within a short period of time the government partnership had incorporated public representation and had split off a citizens committee responsible for planning and objective setting. Members of our team worked with municipal staff, the Langley Environmental Partners (LEPS) and the Salmon River Watershed Management Partnership (SRWMP) to incorporate our research results into environmental planning for the Salmon River watershed and the township as a whole. The Salmon River watershed was also designated a federal-provincial-municipal public demonstration watershed under the Fraser River Basin Management program and has received considerable publicity and praise for its work on community based environmental management.

During the period of our project, the Township, LEPS and SRWMP addressed a number of important local environmental management issues. Members of our team were commissioned to conduct an environmentally sensitive areas study of the Township. Results of the study provided a basis for more informed development decisions by municipal staff and council. Team members worked with municipal staff to develop computer based decision aids for incorporating environmental sensitivity into municipal planning and zoning decisions. Specifically with regard to the Salmon River watershed, the various members of the partnership were successful in replanting streamside vegetation, in convincing land owners to keep domestic livestock away from the stream bank and out of the stream, and in promoting a by-law that required routine maintenance of domestic septic systems. Both programs were based, in part, on research by our team on coho salmon in the river and impacts of domestic waste systems and agriculture on nutrient and pollutant levels in the river. The Township, LEPS and the SRWMP have conducted visible and successful public education programs in environmental awareness including marking storm drains in the Salmon River watershed to inform people that these drain into the river, placing signs along major roadways through the watershed to inform people of the watershed project, producing and distributing a brochure on septic system maintenance, and organizing an annual public picnic to publicize the river and its importance to the community. Early success on the Salmon River and, in particular, the enthusiasm of the Langley Environmental Partners, helped stimulate the formation of three other watershed management groups within Langley Township.

An important issue affecting the Salmon River watershed that the SRWMP has recently been able to resolve is the environmental impact of the pumping station at the river mouth. The pumps prevent flooding of the lower Salmon River when the Fraser River is high. However, the pumps are inadequate to prevent some flooding and water logging of low lying lands near the river mouth in spring and, as a consequence, spring planting is delayed on some fields. The pumps also cause high mortality of juvenile

salmon migrating to sea in the spring. Farmers wanted better pumps to dry up their land faster. Federal and provincial fisheries agencies wanted pumps that are less damaging to migrating fish. Wildlife agencies and enthusiasts, on the other hand, wanted to ensure that wetland habitats near the river mouth would not be jeopardized by more efficient pumps. Although concerns over environmentally appropriate water management in the lower river are important, the major stumbling block to any improvement was funding for the pumps. The Township has recently secured the necessary funding and the new pumping station should not only be more environmentally friendly but will increase the options for water management in the river.

The SRWMP, in combination with Langley Township, LEPS and the other watershed management programs in the Township, has been quite successful in many of its objectives. Experience with the project has identified a number of factors that characterize successful community based management. The first of these is that government agencies, particularly senior government agencies, must be prepared to delegate responsibility to community bodies. Most government agencies are reluctant to make such delegation. Cuts in government budgets, however, have meant that agencies are incapable of carrying out many of their traditional activities. Developing effective co-management with municipalities and community groups is one solution to delivering a high level of service with limited resources. Although many government agencies are uncomfortable with this solution, the Langley partnerships were able to break down enough of these barriers to make real progress.

A second factor is the presence of a strong leader within the community organization. Much of the success of SRWMP and LEPS has been due to the energy and enthusiasm of one individual on the Township staff. Fortunately, the Township has supported the efforts of this individual who undertook the coordination of community co-management as paid employment. Without such an individual championing the various projects and partnerships progress is typically slow and enthusiasm wanes. This stagnation and waning of enthusiasm was evident in two organizations, the Salmon River Enhancement Society and the SRWMP itself when proactive leadership was absent. Although the leader need not be a paid public employee, it is a great advantage when the individual is both an effective leader and paid to do the job.

A third factor is the presence of a tangible problem or set of problems to be solved. The enthusiasm of community groups for such activities as planting trees, marking storm drains and raising fish contrasts strongly with lack of enthusiasm for routine monitoring of stream conditions and attending planning meetings. By contrast, government agencies often have lots of planning experience and expertise but few staff and resources for implementation. This suggests the need for an active but adaptive approach to community management of a watershed with a few clear and relatively straightforward objectives and a proper division of labour among institutional representatives and the public. With proper public consultation, for example, regulatory authorities might make more effective use of their planning capabilities whereas, with proper technical support, community groups can undertake most environmental rehabilitation and restoration projects.

A fourth factor is the availability of suitable technical support. The need for technical support applies at all stages in developing a successful community based project, from advice on how to organize and facilitate a planning meeting to information on the chemistry of water and how nutrients cycle. For the Salmon River watershed project and for the Township of Langley in general, the eco-research project team were able to provide important technical advice and support. The availability of our technical team, including both faculty and students working on environmental issues in the Township, was of considerable importance to the success of the environmental partnerships.

In the municipalities of Abbotsford/Matsqui and Burnaby, members of our team took a similar approach of working with municipal staff on issues of land and water pollution. However, there was less emphasis in these communities on the development of community groups and community based co-management. In Abbotsford the problems included surface and groundwater contamination associated with intensive agriculture, trace metal contamination from natural and human sources, stormwater run-off

from rapidly expanding urban development and flooding in the Sumas River basin. The results of our research on these issues were presented earlier. Much of the research was done in collaboration with municipal and provincial agencies and these agencies provided considerable supplemental funding. In Burnaby the problems included non-point source contamination of the Brunette River system by urban run-off and hazards associated with dangerous goods transportation. At first the municipality was somewhat disinterested in our work, believing there were few cost-effective options for rehabilitating the river system. Over time, however, the municipality came to accept that there were many things that could be done and our eco-research team were able to have considerable influence on multi-level government planning for stormwater management in the Brunette basin.

Our experience in working with these and other communities has shown that much can be accomplished by combining academic and municipal expertise. These successes, however, are very much within the context of existing institutional structures. For many of us it seems unlikely that such an approach will lead to sustainability, although it will certainly build the credibility that will help us to introduce more radical changes in the way that local communities approach the interaction of environment, economy and society.

Additional Research Requirements

Our research has generated new information on many facets of the ecosystem of the lower Fraser basin and the problem of sustainability. We believe that we have provided a coherent picture of the ecosystem and many ideas about what needs to be done to move toward sustainability. However, the task is only begun. Much more research activity is needed, particularly research of the sort that reveals, prods, provokes or facilitates action on sustainability. Furthermore, ongoing research is an integral part of the process of moving toward sustainable development. Changes in policy, designing new programs, monitoring and evaluation all require an underpinning of research activity. Since the environment, the economy and society are continually changing, there is no point at which research ceases to be a requirement.

Contributions to Training

More than forty graduate students and three post doctoral fellows have participated in the project and used or are using research on the project as part of their theses. A complete list of students, and titles of completed thesis are included in the appendix. In addition, more than twenty other students have worked as research assistants on the project.

CONTRIBUTIONS TO POLICY DEVELOPMENT

The specific contribution of any research project to policy development is notoriously difficult to measure. Many individuals and many considerations influence the direction of policy. However, we are confident that our research has already had important effects on policy and will continue to do so for some time to come. The immediate and short term effects of our project on policy have come about through communication of our research results to decision makers at various levels of government, through collaboration with regulatory agencies on the investigation and analysis of specific problems and through working directly with decision makers on the design of new policies. The longer term effects of the project will come about through the continuation of university/community collaborations that began as part of the project, through the leadership provided by our graduates as they take up positions of responsibility in their careers, through the application of tools of policy analysis and development that arose from the project and through the publication and dissemination of research findings in various media.

Ongoing communication of research results to a range of decision makers was one means by which our project influenced policy development in the short term. This communication took the form of reports and short communications on research results circulated to the user community or presented at regional workshops and a series of workshops on issues of sustainable development organized specifically as part of our project. The various written and verbal communications outside the project are listed in the appendix. Here we will summarize the workshops organized as part of the project specifically to communicate results in a timely manner and to get feedback from the user community on our research.

We held 4 workshops over the term of the project that involved decision makers from government, industry and environmental groups as well as representatives of the interested public. The first of these was held at UBC in September 1993. Its purpose was to present our proposals for research and obtain critical comment from potential users. About 60 individuals from government, industry, environmental NGO's and academia attended. In addition to obtaining comment on our research proposals, we used this workshop to establish and strengthen communication linkages with important decision makers. This workshop also allowed us to ensure that our research complemented other major projects within the basin funded under the Fraser River Action Plan. The general consensus from this workshop was that our proposed research was worthwhile, that it would complement other research under the Fraser River Action Plan and that our results would be valuable for policy making. However, there was a sense, particularly from the environmental groups, that we should not get ensnared in academic details but should get on with encouraging and stimulating real action on pressing issues. These comments encouraged us to pay more attention to working directly with municipalities on problems of direct concern to them and to explore more fully the possibilities of collaboration with government research agencies on aspects of the Fraser River Action Plan.

The second workshop was held about 20 months later, in May of 1995, at Kwantlen College in Surrey. It was attended by over 100 individuals from various levels of government and the local community. At this workshop we highlighted the results of research by graduate students in the terrestrial and river and river margins components of our project. The workshop was organized and run primarily by the graduate students. Student presentations addressed 5 important themes: 1) the economic and environmental history of the basin; 2) environmental impacts of human activities in the basin; 3) the pressure of continuing development in the basin; 4) impacts of land use on water quality; and 5) the role of scientific information in policy making. Key issues to be communicated at the workshop were the extent of environmental alteration in the basin over the years deriving from a wide range of human activities, the changing character of human impacts as society and economy evolve, and the growing importance of non-point sources of pollution.

The third workshop was held in January 1966 at the Town and Country Inn, in Delta. The theme of this workshop was non-point sources of pollution and the management of small watersheds. This workshop allowed us to highlight the work that faculty and students had been doing in collaboration with

municipalities and federal regulatory agencies. Topics covered in the workshop included: 1) trace metal and hydrocarbon contamination in an urban watershed and the dangers posed to the watershed by transportation of dangerous goods on highways; 2) contamination from natural sources and intensive agriculture in a rural watershed; 3) nutrient contamination of surface and groundwater in a watershed on the urban/rural fringe; 4) non-point pollution from landfills; and 5) use of computer based decision aids to help municipalities plan more environmentally sustainable patterns of watershed development. The workshop was well attended by representatives from government agencies and the general public.

The fourth workshop was held in October 1966, at UBC. Its purpose was to debate policies for living sustainably in the lower Fraser basin. The workshop highlighted three areas of our research that involved difficult and contentious policy choices: 1) controlling non-point sources of pollution; 2) the social and environmental implications of rapidly changing population and ethnicity in the basin; and 3) the global implications of human activity in the lower Fraser basin. The after an opening plenary session the workshop broke into three groups specifically to discuss ways of dealing with non-point pollution as an example of a pressing local resource issue, ways to engage the community in addressing problems of sustainable development and ways to reduce consumption and enhance social cohesion within communities. About 60 individuals representing municipal, provincial, and federal agencies, non-governmental organizations and the general public participated in the round-table discussions of these issues. With the aid of facilitators each working group addressed the questions: what do we want, what if feasible and how do we accomplish what we want. Two somewhat contradictory conclusions emerged from the working groups. The first was that, although a number of policy reforms were discussed by each group, the complexity of the problems seemed to preclude any clear consensus on what needed to be done. The second was a strong optimism that more sustainable ways of living were feasible and could be made socially attractive and that, with the right kinds of encouragement, these could take root in the communities of the lower Fraser.

Although the workshops provided for a broad dissemination and discussion of our research their influence on policy was only indirect. The most tangible evidence of our impact on policy is through our direct collaboration with municipal decision makers. Details of the research and collaboration that we undertook with the municipalities of Richmond, Burnaby and Abbotsford and the Township of Langley are described in detail earlier in this report. We also undertook less intensive cooperative work with the Greater Vancouver Regional District on environmental planning through our development of the computer game QUEST and with the Fraser Cheam Regional District on development of a regional park. In all of these collaborations, the information and expertise that we were able to contribute to important local problems was both timely and appreciated by municipal and regional officials. In the case of Richmond, we were able to help the staff and council incorporate the concept of the ecological footprint of Richmond into their municipal planning. Richmond has developed a check-list of issues related to the footprint to use in evaluating how proposed by-laws will affect the footprint of the municipality. Much of our work in developing the concept of Social Caring Capacity has also been done with Richmond, so that awareness of this tool is also high in the municipality.

With Burnaby our emphasis has been on the impacts of urbanization on the Brunette River system, the most significant small watershed within the municipality. Partly as a consequence of our research on urban and industrial contamination of the river system and the effects of storm run-off coupled with our analysis of options to reduce or minimize this contamination, the Brunette River has moved well up on the agenda of the municipal council. The higher profile that Burnaby has given to the Brunette system has encouraged the other municipalities with an interest in the watershed (Coquitlam, Port Coquitlam, New Westminster) to begin cooperating with Burnaby on planning to reduce the contaminant loading to the river.

In Abbotsford our involvement was initially with intensive agricultural development in the Sumas basin. As we began cooperating with the local community, however, we also became involved in developing maps for flood management. A major concern in the Sumas valley is the intermittent flooding that occurs when the Nooksack River on the US side of the border floods across a low divide into the Sumas River

which then floods the Sumas valley on the Canadian side of the border. Negotiations are on-going between Canada and the US over how to address the flooding problem. Better maps of potential flood impact in Canada were an important component of these negotiations. Our research on hydrology, land use and water quality in the Sumas basin also led to an assessment of the probable impacts of rapid residential development on the lower slopes of the Sumas mountain. In all cases members of the team associated with studies in the Sumas valley were able to provide relevant and timely information to local decision makers and to influence debates over ongoing development activities within the municipality. Our main contribution in this area was, however, undoubtedly through our analysis of the impact of intensifying agriculture on land and water quality. As described earlier, intensive farming activities in the Sumas valley are creating a serious farm waste management problem. Disposing of excess animal wastes on the limited land base is leading to surface and groundwater contamination in some regions of the Sumas valley. Problems with animal waste disposal are not confined to the Sumas valley and, in response to growing concern over agricultural pollution of streams and aquifers, a Code of Agricultural Practice for Waste Management was developed through multi-stakeholder negotiation and adopted by the Provincial government. Compliance is largely voluntary, however, and our interviews with farmers suggest that the negotiation process was sufficient to raise their awareness but not to motivate their compliance. The management of agricultural practices remains a serious problem in the Fraser valley. As a result of our research decision makers have a much clearer picture of the extent and seriousness of the problem.

We have undertaken a number of cooperative studies with the Township of Langley, all of which have contributed to more environmentally friendly decision making within the municipality. Our involvement with the Salmon River Watershed Management Partnership and our research on water quality and fish habitat in the Salmon River contributed to a range of community run habitat restoration and enhancement projects on the Salmon River. Our analysis of environmentally sensitive areas for the Township provided a set of maps and guidelines for environmentally friendly development within the Township. The analysis was formally adopted by the Township as a basis for development planning. Research on nitrogen levels in aquifers within the Township has highlighted the extent of contamination of aquifers that provide drinking water to a high percentage of Township residents. The research also revealed the important contribution that unmanaged septic systems make to this contamination. As a consequence the Township has adopted a by-law requiring residents to clean their septic systems at least every two years.

Perhaps the best measure of the impact of our research on decision making in these municipalities is that they continue to be enthusiastic about our involvement. Several team members have continued to conduct research in these municipalities and have been successful in obtaining funding from a variety of sources to support their research. This kind of direct community involvement is not a satisfactory arrangement for some kinds of research but where it is, the individuals involved can quickly and directly influence decisions on a wide range of social and environmental issues related to sustainability.

In addition to working with individual communities, we also conducted collaborative research with federal and provincial regulatory agencies as part of the Fraser River Action Plan. For example, the federal Department of Environment provided additional research support for our studies of non-point source pollution in small watersheds. As a result, we participated in a number of workshops and discussions to incorporate the results of this work into decisions arising from the Action Plan. We also participated in a broad study of contaminant burdens in fishes of the lower Fraser coordinated by the Fraser River Estuary Management Program. This study showed that, although contaminant burdens are low and appear to be declining in the lower Fraser fishes, there is a disturbingly high incidence of visible abnormalities in the fishes. The overall results of this work are controversial as they indicate that control of point sources of pollution is no longer capable of preventing increases in contaminant loading to the basin as population increases, agriculture intensifies and atmospheric loading go up. Most measurable contaminants are below concentrations considered safe for human health although nitrogen contamination of well waters is of growing concern as is trace metal contamination in some locations. However, organisms in the lower Fraser are subject to a very broad spectrum of contaminants at low concentration and we have very little information on the health consequences of such exposure. High incidence of

visible abnormalities in fishes may be an early warning signal that ecosystem health is being jeopardized. We are still working to confirm some of the more disturbing aspects of this research but we believe that, if present results are confirmed, it will have far reaching consequences for decision making not only in the lower Fraser but for similar ecosystems world wide.

New information is only one of the products of our research that will influence policy. Probably the more significant influence will come through the employment of students who obtained degrees through the project. The project provided the opportunity for these students to rub shoulders with faculty and students from a range of disciplines and most of them took advantage of the opportunity. A high proportion of the students was also enrolled in an interdisciplinary studies program that required them to take courses in more than one discipline and to pursue research that was interdisciplinary. Many of the students also worked on research projects that put them in daily contact with non-academic practitioners in government and municipal offices. As a consequence, the students were exposed to the diversity of academic and professional viewpoints on environmental management and sustainable development and saw first-hand the difficulties of implementing new policies in real life. We are confident that these students will bring a breadth of knowledge and a pragmatism to their careers that will have lasting influence on future environmental management in the lower Fraser and elsewhere.

Our graduates will enter the work force not only with new knowledge and new, more integrative ways of analyzing problems but also with several new tools for policy development and analysis. These tools include the computer based scenario generation and analysis tool, QUEST, the Ecological Footprint Analysis (EF), the Social Caring Capacity Analysis (SCC) and Geographical Information Based decision support systems. EF and SCC were both utilized in our collaborative research with Richmond but the EF analysis is being used internationally as a tool to raise awareness of the extent and insecurity of national dependence on ecological services from other regions of the globe. The tool of EF analysis was developed prior to our project. However, the project provided support for the continued elaboration of the tool in a specific regional context and the results of EF analysis for the lower Fraser provide an important example in international comparisons. QUEST has only recently become operational as a policy analysis tool but is already generating international interest. Students who developed the model have been invited to demonstrate its potential in the US, New Zealand, Thailand and Hong Kong and a number of institutions have offered funding to assist with further development of the tool for use in other geographic locations.

Overall, we feel that our influence on policy has been considerable, particularly at the local level, and results of our project are beginning to have impact at the international level. We fully anticipate that the project will continue to have influence on policy and decision making locally and internationally as more of the results are synthesized and published and as our graduates begin to have an impact through their careers. A number of the faculty that were involved with the project have continued to conduct research in collaboration with municipal and other government agencies, which will also extend the influence of our project. The influence of our project on Canadian national policy is more difficult to judge. However, we anticipate that the range of information and ideas that emerge from the eco-research projects as a whole will have a lasting influence on national decision making as well.

ALLIANCES AND DISSEMINATION

Details of our most significant research collaborations with government agencies in the lower Fraser basin and the benefits of that collaboration have been described in detail earlier. Members of our research team collaborated with the municipalities of Richmond, Abbotsford, Langley Township and Burnaby, with the Greater Vancouver Regional District and with the Fraser Cheam Regional District, with the federal departments of Environment and Fisheries and Oceans, with the provincial ministry of Environment Lands and Parks and the BC Statistical Office, with the Fraser Estuary Management Program and with colleagues in Quebec, Great Britain and the US. As we noted earlier, these collaborations both enriched our research opportunities and provided a network of contacts through which to communicate the results of our research. For a project such as ours, this kind of networking is fundamental to successful

dissemination and acceptance of results. For the agencies with which we were collaborating members of our team were not simply anonymous academics but individuals in whom they had developed some trust and respect. One of our collaborators, who attended the national workshop on eco-research projects, commented that he felt many of the university participants at the workshop had missed the point of eco-research. In this person's opinion, the most significant benefit of eco-research was to forge just the kind of collaborative linkages with regional government agencies that we found so successful.

In addition to information transfer through the collaborations noted above, members of the research team have so far published or submitted for publication 78 papers in scholarly journals or other formal academic media, produced 26 working papers for local distribution, given 42 talks and lectures, 23 of which were to local public audiences, and participated in several public workshops to discuss results of the project. Chapters have been completed for one book on the project and a second is in the planning stages.

Our research project can be accessed on the World Wide Web at: http://www.ire.ubc.ca/ecoresearch/. The text of this final report can be downloaded from our web site.

APPENDIX 1
FACULTY, STAFF AND STUDENT COLLABORATORS

WHOLE BASIN COMPONENT

FACULTY PARTICIPANTS

Name	Department	Specialty
Michael Healey (component leader)	Westwater Research Centre	Ecology
John Robinson (component leader)	Sustainable Development Research Institute	Environmental Science
Neil Guppy	Anthropology and Sociology	Sociology
Brian Elliott	Anthropology and Sociology	Sociology
Les Lavkulich	Resource Management and Environmental Studies	Soil Science
Ron Shearer	Economics	Economics
Bob Woollard	Family Practise	Medicine
Bill Rees	Community and Regional Planning	Planning
Barbara Zeigler	Fine Arts	Print Making

RESEARCH ASSOCIATES, POST DOCTORAL FELLOWS, RESEARCH ASSISTANTS

Name	Department
John Sproul	Economics
John Richardson	Westwater Research Centre
Clay Mosher	Anthropology and Sociology
Janette MacIntosh	Family Practise
Bruce Arai	Anthropology and Sociology
Fiona Peterson	Resource Management and Environmental Studies
Alice Wong	Westwater Research Centre
Serena Arduino	Community and Regional Planning
Victor Wong	Westwater Research Centre
Chantelle Marlor	Anthropology and Sociology

ADMINISTRATION

Name	Department
Janet Land	Sustainable Development Research Institute
Christine Massey	Sustainable Development Research Institute

STUDENTS

Name	Department
Mike Walsh	Resource Management and Environmental Studies
David Biggs	Sustainable Development Research Institute
Emese Kiss	Sustainable Development Research Institute
Christina Tague	Sustainable Development Research Institute

RIVER AND RIVER MARGINS COMPONENT

FACULTY

Name	Department	Specialty
Michael Healey (component leader)	Westwater Research Centre	Ecology
Neil Guppy (component leader)	Anthropology and Sociology	Sociology
Ken Hall	Westwater Research Centre	Pollution Chemistry
Hans Schreier	Westwater Research Centre	Soil Science
Tim McDaniels	Community and Regional Planning	Decision Analysis
Brian Elliott	Anthropology and Sociology	Sociology
Michael Kew	Anthopology and Sociology	Aboriginal Peoples
Bruce Miller	Anthropology and Sociology	Aboriginal Peoples
Don Blake	Political Science	Political Systems
Dev Jennings	Commerce	Organizational Systems
Paul Harrison	Botany	Ecology

RESEARCH ASSOCIATES, POST DOCTORAL FELLOWS, RESEARCH ASSISTANTS, EXTERNAL COLLABORATORS

Name	Department
John Richardson	Westwater Research Centre
Scott Hinch	Westwater Research Centre
Larry Axelrod	Westwater Research Centre
Alice Wong	Westwater Research Centre
Nigel Cavenaugh	Community and Regional Planning
Dori Bixler	Anthropology and Sociology
Aaron Doyle	Anthropology and Sociology
Chantel Marlor	Anthropology and Sociology
Peter Urmetzer	Anthropology and Sociology
Jeff Laurien	Community and Regional Planning
Sabine Tamm	Community and Regional Planning
Milena Calendino	Forestry
Aimee Lau	Geography
Pauline Landry	Westwater Research Centre
Karri Long	Westwater Research Centre
Tony Marotta	Civil Engineering
Rick Palmer	Westwater Research Centre
Zoe Redenback	Resource Management and Environmental Studies
Arlene Strom	Political Science
Andrea Kastner	Education
Paul Slovic	Decision Research Associates, Oregon

STUDENTS

Name	Department
Jim Echols	Westwater Research Centre
Randy Lake	Westwater Research Centre
Paul Zandbergen	Resource Management and Environmental Studies

Caroline Berka	Resource Management and Environmental Studies
Barbara Aldritt	Anthropology and Sociology
Dean Barry	Anthropology and Sociology
Tim Lissimore	Westwater Research Centre
Sherry Boudreau	Resource Management and Environmental Studies
Alison McNeill	Anthropology and Sociology
Don McCallum	Civil Engineering
Heather Mathews	BioResource Engineering
Gillian Larkin	Civil Engineering
Cristel Rasmussen	Botany
Raewyn Bassett	Anthropology and Sociology
Vivien Clark	Commerce
Pamela Dymond	Westwater Research Centre
Melissa Fletcher	Zoology
Celine Marboulis	Anthropology and Sociology
Laura Rempel	Westwater Research Centre
James Smith	Civil Engineering

TERRESTRIAL COMPONENT

FACULTY

Name	Department	Specialty
Les Lavkulich (component leader)	Resource Management and Environmental Studies	Soil Science
Ron Shearer (component leader)	Economics	Economics
Fred Ganders	Botany	Zoogeography
Hans Schreier	Soil Science	Soil Science, GIS
Victor Lo	BioResource Engineering	Nutrient Modelling
Dave Turpin	Botany	Physiology
Tony Scott	Economics	Economics

RESEARCH ASSOCIATES, POST DOCTORAL FELLOWS, RESEARCH ASSISTANTS, AND EXTERNAL COLLABORATORS

Name	Department
John Sproul	Economics
Helen Kennedy	Botany
Angelito Vizcarra	BioResource Engineering
Carol Boyle	Resource Management and Environmental Studies
Michael Mortinson	Geography
James McQueen	Forestry
Amanda Breslin	Soil Science
Fiona Peterson	Resource Management and Environmental Studies
Frank Lomer	Amateur Botanist

STUDENTS

Name	Department
Ute Pott	Botany
Katherine Wreford	Soil Science
Vera Top	Soil Science
Susan Ames	Soil Science
Kim Anderson	Soil Science
Cherie Metcalf	Economics
Dawn Pascreata	Resource Management and Environmental Studies
Richard Porter	Forest Science
Cindy Sayre	Botany
Alfred Vickery	Economics
Barbara Wernick	Resource Management and Environmental Studies
Peter Urmetzer	Anthropology and Sociology
Susan Petersen	Resource Management and Environmental Studies

SUSTAINABLE URBAN SYSTEMS COMPONENT

FACULTY

Name	Department	Specialty
William Rees (component leader)	Community and Regional Planning	Planning
Robert Woollard (component leader)	Family Practise	Medicine
Peter Boothroyd	Community and Regional Planning	Planning
Sharon Manson Singer	Social Work	Social Analysis
Clyde Hertzman	Health Care and Epidemiology	Risk Analysis
Judith Lynam	Nursing	Public Health
Lawrence Green	Health Promotion Research	Public Health

RESEARCH ASSOCIATES, POST DOCTORAL FELLOWS, RESEARCH ASSISTANTS

Name	Department
Janette McIntosh	Family Practise
Aleck Ostry	Health Care and Epidemiology
Graham Beck	Community and Regional Planning
Anthony Parker	Community and Regional Planning
Molly Harrington	Community and Regional Planning
Lesley Aronson	Social Work
Melanie Charles	Nursing
Brian Kerin	Biology
Jill Melody	Westwater Research Centre
Karen Thomas	Community and Regional Planning
Lynn Tolland	Forestry
Melanie Brown	Anthropology and Sociology

STUDENTS

Name	Department
Yoshi Wada	Community and Regional Planning
Mathis Wackernagel	Community and Regional Planning
Mike Carr	Community and Regional Planning
Jennie Moore	Community and Regional Planning
Alec Ostry	Health Care and Epidemiology
BonnieJeffrey	Health Promotion Research
Cindy Sutherland	Community and Regional Planning
Lyle Walker	Community and Regional Planning

APPENDIX 2
SEMINARS, REPORTS, PUBLICATIONS

Seminars, Symposia, Posters and Displays

Bixler, Dorinda S. Navigating the Crosscurrents: Charting Interdisciplinary Approaches to Sustainability Research in the Lower Fraser Basin. A Presentation given at Conference on Environment, Development and Health, Society for Applied Anthropology Annual Meeting 29 March 1995.

Bixler, Dorinda S. Homeward Bound, Common Ground: A Journey Through Personal Experience, Anthropological Research and First Nations' Perspectives to Identify Boundaries and Linkages for Interdisciplinary Research in the Lower Fraser Basin. A Presentation given at Symposium on Moving Beyond The Boundaries: Exploring Interdisciplinary and Collaborative Research, Seventh Annual Anthropology-Sociology Student Symposium, 11 March 1994.

Blake, D. E., N. Guppy, and P. Urmetzer. Environmental concern and environmental action. Presentation to the Political Science Department Faculty/Graduate seminar, UBC, 27 September, 1996

Blake, D. E., N. Guppy, and P. Urmetzer. Environmental attitudes and transportation policy in the lower Fraser basin. Geography Department Colloquium, UBC, 21 March, 1997.

Green, L. W., and C. J. Frankish. Health and social policy: cooperation among individuals, communities and centralized organizations in health promotion. Presentation given at: The National Symposium of the Netherlands Heart Foundation and the Association of Municipal Public Health Services, 9 November 1994; The Israel Public Health Association, Jerusalem, 10 November 1994; and The Victoria Health Promotion Foundation, Melbourne, Australia, 15 November 1994.

Hall, K. and students. Non-point pollution in the Brunette River watershed. Presentation to the Environment and Waste Management Committee of the Municipality of Burnaby, October 1994.

Hall, K. J. 1997. Non-Point pollution from stormwater runoff in the Brunette River watershed. Presentation to the Vancouver Natural History Society, Feb. 27, 1997.

Hall, K., and H. Schreier. 1996. Acting on Non-point sources of pollution. Workshop on Policies for living sustainability in the Lower Fraser Valley. Eco-Research Project, University of British Columbia, Vancouver, Oct. 3, 1996

Hall, K., H. Schreier and W. Tamagi. 1997. Water Quality and Non-point source Impacts. Urban Steam Protection and Stewardship in the Pacific Northwest. Are we achieving desired results? Technical Workshop, Department of Fisheries and Oceans and Ministry of Environment. New Westminster, B.C. March 10-12, 1997.

Healey, M. C. Integrating natural, health and social sciences in the lower Fraser basin eco-research project. Presentation given at the International Group of Funding Agencies for Global Change Research meeting, Vancouver, September 1994.

Healey, M. C. The lower Fraser eco-research project. Presentation given at: The First International Symposium on Ecosystem Health and Medicine, Ottawa, June 1994 and the International Association of Funding Agencies, Vancouver, February 1995.

Healey, M. C. Carbon, contaminants and fish. Presentation given at: Workshop on habitat management of the Fraser Estuary, Vancouver, April 1995.

Healey, M. C. Guaging the health of the Fraser Valley ecosystem. Presentation given at Chilliwack, March, 1995.

Healey, M. C. Poster presentation on the lower Fraser eco-research project. 2nd annual E-MAN workshop, Halifax, NS, 1996.

Hertzman, C. What's been said and what's been hid: Population health, global consumption, and the role of national health data systems. Presentation given at: The International Centre for Health and Society Conference, London, England, 1994.

Jennings, D.,and V. Clark. Paper for upcoming conference: Role of the Actor in Institutional Theory. Interview studies examining development and implementation of water quality standards.

Lavkulich, L. M., et al. *The Lower Fraser Basin in Transition.* Symposium given by Terrestrial and River / River Margins Components student researchers to government and community participants at Kwantlen College, Surrey, B.C., May 4, 1995. Proceedings published under same title.

Lavkulich, L. M. Nutrient loading and assimilation. Symposium, B.C. Hog Producers, B.C. Ministry of Agriculture, Food and Fisheries, Abbotsford, B.C., February 1995.

Lavkulich, L. M. Eco-research; integration of land-water and sustainability. Simon Fraser University Department of Geography and School of Environment and Resource Management, February 1996.

Lower Fraser Basin Eco-Research Project: Overview. Developed for National Environment Week. On display at Eaton's Centre in Metrotown, Burnaby, B.C., June 8 - 10.

McDaniels, T., and L. Axelrod. Characterizing Perceptions of Ecological Risk. Presentation given at: Decision Research, Eugene, Oregon, May 1994; Carnegie Mellon University, September, 1994; Simon Fraser University, March 1995.

McIntosh, J. Planning for Sustainability: Tools for Promoting Personal, Community and Ecosystem Health. A presentation and poster session at the First International Symposium on Ecosystem Health and Medicine, Ottawa, June 19-23, 1994.

McIntosh, J. and S. Carter. Planning for Healthy and Sustainable Communities: Joint efforts being attempted by a UBC Task Force and the City of Richmond. Joint case study presentation with the City of Richmond, Senior Planner, at "Design Choices for a Sustainable Future", a one day conference during Design Week '94, Vancouver, B.C., March 11, 1994.

McIntosh, J., and M. Roseland. Sustainability: background, basic principles and examples. At a Sustainable Communities Workshop, Kimberley, B.C., April 23, 1994.

McIntosh, J. and M. Wackernagel. Working toward healthy and sustainable communities. Teaching about healthy and sustainable communities. Workshops conducted at Community Interaction Day and Professional Development Day, Comox Valley, B.C., May 5-6, 1994.

McIntosh, J., M. Wackernagel, and J. Moore. Planning for Sustainability. Poster session at Greening Our Cities Conference, Vancouver, B.C., May 7-8, 1994.

Richardson, J. S. and M. C. Healey. Autocorrelations in ecosystems across space, time, and disciplines: the case of the Fraser River. Presentation at the Workshop on Sampling Design for Aquatic Networks Across Scales, Portland, OR, September 1994.

Richardson, J. S. and M. C. Healey. Fish assemblages of the lower Fraser River: comparisons over 20 years. Canadian Conference for Fisheries Research, Ottawa, January 1995.

Richardson, J. S., M. C. Healey, and T. Lissimore. Fish assemblages of the lower Fraser River: comparisons over 20 years. North Pacific International Chapter Meeting of the American Fisheries Society, Vancouver, April 1995.

Schreier, H. and K. Hall. 1996. Non-point source pollution and GIS in urban and urban/rural fringe watersheds; A Hypertext presentation. Annual Meeting of the Canadian Municipal Environmental Managers. April 23, 1996, Vancouver, B.C.

Schreier, H. Berka, C. and S. Brown. 1996. Land and Water Resource dynamics in the Sumas Watershed. Sumas Prairie Sustainability Study. Abbotsford City Hall, April 25, 1996 Presentation to the Engineering and Planning Department, Abbotsford, B.C.

Schreier, H., K. Hall, and L.M. Lavkulich. 1996. Non-point sources of pollution and implications for watershed management. One day workshop on environmental issues relating to water resource degradation from urbanization, agriculture and population expansion in the Lower Fraser Valley. Delta, B.C. ECO-Research Project Results, January 24, 1996. 180 participants.

Schreier, H. 1996. A Hypertext approach to modelling non-point source pollution. Environment Canada, Water Management Branch, Vancouver, May 6, 1996

Schreier, H. 1996. An overview of the groundwater and streamwater issues in Fort Langley. Economic and Environmental Advisory Committee for the Township and interested citizen. June 5, 1996 in Fort Langley.

Schreier, H. 1996. Groundwater management strategies in the Sumas River basin. Presentation to Mayor and Council, Township of Langley, Langley, B.C. Oct. 7, 1996

Schreier, H and K. Hall 1996. Issues in streamwater management in the urban environment. Public presentation to the Salmon River Enhancement Society, Langley Environmental Partners Society (LEPS) and interested citizens. Walnut Grove Secondary School, Oct. 29th, 1996 (70 participants)

Schreier, H. and K. Hall. 1996. Non-point sources pollution issues in an urban watershed context. Applications in stormwater quality. Annual Meeting Canadian Society of Civil Engineering, Sidney, B.C. Sept. 27, 1996 (invited presentation).

Schreier, H. and K. Hall. 1997. Non-point sources of pollution: Innovations at the municipal level. To: Mayor and Council: District of Chilliwack, May 28, 1997

Sproul, J. Reconciling monetary value and eco-system value. Presentation at the Fisheries Centre, U.B.C.

Sproul, J. Economic history of the Fraser River valley. Presentation at two schools in Whatcom County, WA.

Top, V. and L. M. Lavkulich. Dissipation of four common pesticides applied to a lower Fraser valley soil. Alberta soil science workshop, Grande Prairie, AB, February 1995.

Top, V., L. M. Lavkulich and S. Szeto. Dissipation of pesticides applied to berry crops in the lower Fraser valley. Amer. Assoc. Adv. Science Annual Meeting. Vancouver BC, June 1995.

Top, V. and L. M. Lavkulich. dissipation and mobility of four pesticides in the lower Fraser velley of BC. Symposium on non-point sources of pollution and implications for watershed management. Institute for Resources and Environment, UBC, Delta, BC, January 1996.

Woollard R. Embedded Systems: Human, Community and Eco-system Health. Presentation at: The First International Symposium on Ecosystem Health and Medicine, Ottawa, June, 1994.

Working papers

Anon. 1996. Living sustainably in the lower Fraser basin (produced by the Eco-research graduate student forum).

Biggs, D. 1994. A description of the proposed lower Fraser basin scenario generation tool.

Blake, D. E., N. Guppy, and P. Urmetzer. 1996. Being green in British Columbia: Public Attitudes toward environmental issues. Discussion paper dp-37, Centre for research on economic and social policy, UBC.

Brown, Melanie. 1994. Preliminary reports on the political culture and on the community leaders of Abbotsford and Matsqui.

Doyle, Aaron. 1994. A brief social history of the Abbotsford/Matsqui region.

Elliott, B. and N. Guppy. 1996. Living sustainably in the lower Fraser basin: policy implications of the sociological studies. prepared for the policy workshop, October 1996.

Graduate Student Forum. 1996. Living sustainably in the lower Fraser basin. A report of some findings of the lower Fraser basin eco-research project.

Hall, K., and H. Schreier. 1996. Acting on non-point sources of pollution. prepared for the policy workshop, October 1996.

Healey, M. C. and Alice Wong. 1993. Background material for the first eco-research workshop, Asian Centre, UBC.

Healey, M. C. 1994. First annual report of the lower Fraser basin eco-research project.

Healey, M. C. 1995. Second annual report of the lower Fraser basin eco-research project.

Ip, Catherine. 1995. The tapestry of the Chinese community: change and continuity.

MacIntosh, J. 1996. Summary report of workshop on interdisciplinarity in the eco-research project: reflections on the lower Fraser basin study. June 1996.

Marlor, Chantal. 1994. Socio-demographic profile of Abbotsford and Matsqui 1991.

Rees, W. 1996. Toward living sustainably in the lower Fraser basin: policy implications of eco-footprint analysis. Prepared for the policy workshop, October 1996.

Richardson, J.S. and M.C. Healey. Autocorrelations, discontinuities, and environmental monitoring: the case of the Fraser River.

Sandhu, Arjan. 1995. South Asians of the Fraser Valley.

Schreier, H., K. Hall, and L. Lavkulich. 1996. Abstracts for the workshop on non-point sources of pollution and implications for watershed management. January 1966.

Shearer, R. A., and J. T. Sproul. 1995. Clear-cutting in the lower Fraser basin: some institutional considerations. May 1995.

Shearer, R. A., and J. T. Sproul. 1996. The genesis of the Coquitlam Lake conservation reserve: A footnote on early conservationi policy in the lower Fraser basin.

Shearer, R. A., and J. T. Sproul. 1996. The lower Fraser basin, its landscape and its people: an historical perspective.

Wackernagel, M. 1994. How Big is Our Ecological Footprint?: Using the Concept of Appropriated Carrying Capacity for Measuring Sustainability. A brochure originally printed in 1993, revised in 1994.

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Department of Water Resources
Reprographics