Stuart-Takla Fisheries/Forestry Interaction Project:

Research Design Workshop

by

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ABSTRACT


This document summarizes discussions from a three-day research planning workshop held in February 1994. The workshop focused on potential effects of timber harvesting in the Stuart-Takla watershed on fisheries resources, but water, sediments, aquatic biota, and habitat were also considered and discussed in detail.

Building upon existing conceptual models, participants developed impact hypotheses for the Stuart-Takla watershed, focusing on water, sediment, and fish, and covering the entire area from the uplands through the riparian-zone and floodplain, and into the channel. Then, using the revised conceptual models as a guide, important information needs and key data gaps were catalogued. Management questions and impact hypotheses to be tested in this program were identified. Participants then developed or refined experimental approaches to, and tests for, the scientific questions and impact hypotheses. Wherever possible, existing research projects and study designs were incorporated into the research plans. The final plenary session included a discussion of options for experimental timber harvesting.
ACKNOWLEDGEMENTS

This workshop was sponsored by the Integrated Management Branch of the B.C. Ministry of Environment, Lands and Parks. Geoff Chislett offered introductory remarks, and helped to set the context for the workshop. Steve Macdonald provided a concise overview of past relevant research at this location.

Workshop design and arrangements were provided by ESSA Technologies Ltd., with input and advise from members of a steering group composed of: Dan Hogan, Tom Johnston, Dan Lousier, and Steve Macdonald. Thanks are due to all of the workshop participants, most of the report contents consist of their ideas, either born or contributed during group discussions. A list of participants, along with affiliation and contact information, is provided in Appendix A. Special recognition is due Dan Lousier, who ably stepped in to serve as facilitator for the upland subgroup.

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INTRODUCTION

Overview

This document provides a summary of results obtained during a three-day research planning workshop held in February 1994 in Richmond, B.C. The workshop focused on the potential effects of timber harvesting in the Stuart-Takla watershed on fisheries resources. Intermediate mechanisms were also considered and discussed in detail - water, sediments, aquatic biota, and aquatic habitat. Overall, the goal of the workshop was to create a forum for discussing and refining research plans, addressing integration issues, and identifying preferred options for experimental timber harvesting activities. The 20 participants and three facilitators who attended the meeting are listed in Appendix A.

Background

As Macdonald and co-workers (1992) pointed out, the relationships between forest harvesting activities and productive capabilities of interior B.C. aquatic environments are only poorly understood. Unlike the situation for coastal systems, there has been relatively little research in the interior upon which to base logging guidelines. Previous work near Prince George, B.C. (Slim Creek) and Edson, Alberta (Tri-Creeks) provides useful, but limited data. Regional differences in hydrology, climate, geology, and biology interfere with attempts to apply data and information from the coastal research programs at Carnation Creek and in the Queen Charlotte Islands.

The Stuart-Takla watershed is northwest of Prince George, B.C. and is the northernmost extent of the Fraser River drainage. In the Stuart-Takla there are a number of sub-basins that have had little forestry disturbance, to date. Moreover, creeks and rivers in this drainage support important anadromous sockeye salmon (Oncorhynchus nerka) and kokanee populations, along with smaller numbers of other fish species, including rainbow (Salmo gairdneri) and bull trout (Salvelinus malma), sculpins (Cottus), burbot (Lota lota), dace (Rhinichthys sp.), whitefish
(Coregonus sp.), and suckers (Catostomus sp.). The Stuart-Takla drainage contains several creeks that are highly productive sockeye salmon systems; escapements there have been monitored since 1938. Some streams in this drainage are known to receive up to 60 thousand spawning sockeye salmon in a season, with other nearby creeks receiving over 10 thousand spawning fish each.

Partly as a result of a forest insect epidemic, summer and winter logging activities have been initiated in recent years in the Stuart-Takla drainage. These forest harvesting efforts provide an opportunity to investigate interactions between forest harvesting and fish production in the central interior. Such studies will lead to an improved data and knowledge base for formulating effective logging guidelines for this region.

To improve the understanding of ecosystem processes affecting anadromous fish production in the interior, and to investigate how forestry practices affect fish populations, the Department of Fisheries and Oceans initiated in 1992 a Fishery/Forestry Interaction Project in the Stuart-Takla drainage. The B.C. Ministry of Forests was the next partner to join research efforts in these watersheds, and is now the second largest financial contributor to the overall program. Later, the B.C. Ministry of Environment, Lands and Parks joined in, and now there are a number of other institutions and individuals working in, or planning to join the research effort in the Stuart-Takla drainage (see Appendix B). As more researchers join the program, the initiative will become more of an integrated, ecosystem study.

It is within an ecosystem context that the broad framework of the Stuart-Takla Experimental Forest (Lousier 1993) was conceived. As the scope of the program expands, and the number and types of research programs grow, it will become increasingly important to actively promote and foster integration among projects and investigators. The research planning workshop described in this report was an attempt to champion integration and to ensure that the proposed research is targeted at the real and current needs of managers and policy-makers.
Management Questions and Issues

Research planned for the Stuart-Takla experimental watershed is intended to generate data and provide information needed to better manage interactions between the forestry and fisheries sectors in interior B.C. ecosystems. Because the relevant and available data and information for this region of the province are inadequate, it seems reasonable to begin by identifying key management questions and issues that should be addressed by such a research program. While our knowledge of any ecosystem is always incomplete, in this case the effort is on providing policy- and management-relevant information that will permit managers and policy-makers to direct forestry operations toward practices that are more sustainable, and that have less impact on aquatic ecosystems.

The workshop participants identified six main areas of management concern, but recognized that not all of these can be well addressed through work at the Stuart-Takla:

1. acceptable level of streamside logging: as illustrated in Fig. 1, there is some (as yet unknown) relationship between the size and quality of the leave strip beside a stream and the quality of the fish habitat. For interior watersheds in this region the size, shape, and location of leave strips needed to adequately protect aquatic biota and habitat is currently ill-defined. However, experimental designs to provide such information may be frustrated by the new provincial Forest Practices Code, which stipulates that logging to the edge of salmon-bearing streams is an unacceptable practice. Nevertheless, because the effectiveness of treatments for forest insect pest outbreaks may be enhanced by streamside logging, a better understanding of this relationship would clearly be of practical use;

2. road density, location, and quality: this can affect aquatic habitat and biota, but is influenced by factors such as soil type, terrain, and slope. Concern has been raised over the maintenance of roads and their eventual deactivation. As well, there is a need to know more about how the quality of winter roads affects aquatic
ecosystems. The success of different road rehabilitation techniques needs to be studied and documented;

3. stream crossings: to protect in-stream habitat, and evaluate the trade-offs between summer and winter logging activities, more and better information is needed about effects of temporary crossings and winter roads, skidding, forest vegetation removal, soil compaction, and so forth;

4. rate-of-cut: this can be managed a number of ways by altering factors such as cut-block size, cumulative area exposed, and applying efforts to rehabilitate affected areas. Development of suitable criteria will depend on having more information than is currently available. However, the limited amount of commercial timber in the Stuart-Takla watersheds makes it difficult to fully address this issue;

![Graph showing the relationship between Leave-strip width or quality and Fish Habitat Quality.

**Figure 1:** Hypothetical relationship between size or quality of leave-strip and fish habitat quality.
5. rate of hydrologic recovery: one key unknown is how quickly the hydrologic regime will return to pre-harvesting levels. This has implications not only for transport of bedload and large organic (e.g., woody) debris (LOD), but also stream water temperature. Again, because of the limited amount of commercial timber, it may be difficult to study hydrologic recovery in the Stuart-Takla watersheds; and

6. adequacy of guidelines: there are a number of guidelines and codes that apply to forest harvesting in interior B.C. Improved knowledge and more data could help in specifying appropriate rates of re-vegetation, suitable road opening widths, siting bridges, and dealing with contaminants from fuels, lubricants, and treated timbers.

Report Organization

The remainder of this report is organized as follows: Chapter two describes the workshop approach to research planning, while Chapters three through five present results from the three subgroup meetings. Each of these three chapters follows roughly the same format: 1) conceptual model; 2) desired data and information; 3) research hypotheses; 4) experimental approaches; 5) relationship to other study components; 6) options for experimental timber harvesting; and 7) a short-term action plan. Chapter six then provides a brief synopsis of the plenary discussions, while Chapter seven briefly summarizes the main findings. Appendix A identifies workshop participants and Appendix B identifies research agencies and their current activities in the Stuart-Takla region. A few terms are defined and presented in the Glossary.
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METHODS

Approach

Prior to the workshop there was a meeting of the steering committee to discuss workshop design and logistics. We also briefly discussed the background paper. Prior to the workshop, each participant received a briefing package that contained a draft conceptual model for their review. The workshop program was designed to be efficient and effective, and was guided by facilitators from ESSA Technologies. This was helpful, for the participants had to cover a considerable amount of conceptual territory in a relatively short time. The workshop consisted of a few brief, introductory talks that summarized the intent and evolution of the project, followed by a general discussion of the conceptual model and specific charges to the three subgroups (upslope, channel, biota). The subgroups initially made revisions to the conceptual model and defined the necessary information exchanges among subgroups. The greater portion of the workshop was subsequently spent in subgroups identifying issues and impact hypotheses. The subgroups met towards the end of the workshop to present and synthesize their revised models and information needs, and to consider experimental design.

Draft Conceptual Model

Before the workshop began we offered two conceptual models as first-cut "straw men", designed to serve as a starting point for the workshop discussions. In both figures we attempted to capture the major mechanisms and their linkages, rather than portraying all of the underlying processes. It was recognized that there is a rich and complex array of interrelationships one level below that illustrated in these figures. During the workshop, each subgroup had the opportunity to expand upon the relevant portions of the conceptual model(s) that emerged from the initial plenary session. However, it was important that before breaking into subgroups the participants all agreed on an overall conceptual map.
Perhaps the most important decisions that are made in any research design exercise are the key issues of concern and the choice of components to be explicitly considered in addressing these issues. These choices are identified through what is known as a bounding exercise (see Glossary). In the case of the Stuart-Takla FFIP, much of this work had already been done, so this exercise was more of a reiteration to ensure that all the participants were beginning from the same place, conceptually. The bounding exercise also forced participants to define a finite and realistic set of perturbations (actions), identify specific indicators, and to place them both in an appropriate spatial, temporal, and hypothesis framework.

The draft conceptual diagram shown in Fig. 2 focuses on fish spawning habitat, egg survival, and hatching, as they are affected by mechanisms like changes in stream temperature or discharge. In contrast, Fig. 3 focuses on fish growth and is built around mechanisms like changes in fine organic sediments and woody debris. These two diagrams were used as suggestions, and represent a synthesis of information taken from a variety of sources (e.g., Hartman and Scrivener 1990; Korman et al. 1992; Macdonald et al. 1992; McNamee et al. 1987; Meehan 1991; Naiman 1992).

These draft conceptual models represent an interrelated set of impact hypotheses. An impact hypothesis is simply a description of a hypothesized relationship that exists between some action and an expected response by a part of a natural system. The simplest form of an impact hypothesis contains reference to a specific "action" and to the expected change in a specified "indicator". For example:

*The construction of roads and stream crossings will increase suspended sediment levels in streams.*

In the workshop we used the revised conceptual diagrams to aid us in first recognizing important information needs and key data gaps, and then in identifying scientific questions and impact hypotheses to be tested in this program. This was a very important step toward developing or refining the experimental approaches to, and tests for, the scientific questions and impact
Figure 2: Potential impacts of timber harvesting on fish spawning and egg hatching success. Key processes or pathways are numbered from 1 to 23.
Figure 3: Potential impacts of timber harvesting on juvenile fish growth.
hypotheses. Table 1 contains a series of questions that were designed to help elaborate and assess the impact hypotheses.

**Table 1:** Questions to help elaborate and assess impact hypotheses.

<table>
<thead>
<tr>
<th>Actions</th>
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<tbody>
<tr>
<td>1. What actions (timber harvest activities) need to occur to test the hypothesis?</td>
</tr>
<tr>
<td>2. Are these actions feasible? (i.e. do they comply with the draft guidelines? Are existing guidelines a necessary constraint to experimental treatments at all spatial scales?)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. What indicators need to be measured to determine if the hypothesis is correct? (i.e. what are the indicators for the uncertain linkages?)</td>
</tr>
<tr>
<td>4. Are these indicators part of the current study design?</td>
</tr>
<tr>
<td>5. If so, is there enough baseline data on these indicators to quantify their natural spatial and temporal variability, and assist in the experimental design?</td>
</tr>
<tr>
<td>6. If the answer to questions 2 and/or 4 is &quot;no&quot;, can these research needs be met elsewhere (synoptic studies)? If so, where?</td>
</tr>
<tr>
<td>7. What level of change in these indicators would be considered ecologically significant? What level of change in these indicators would be detectable, given the historical data base, and the intended intensity of sampling?</td>
</tr>
</tbody>
</table>

When we began discussing hypothesis testing we tried to take into account:

1. details of the experimental treatment (e.g., clearcut size, buffer strips, road location, crossing design);

2. habitat measurements (e.g., sedimentation, spawning gravel composition, water export and flows (volumes, velocities, and depths), large organic debris, water temperature, dissolved oxygen, primary production);
3. population measurements (e.g., numbers for each life cycle stage, growth, spatial distribution, behavioral changes); and

4. other factors that will need to be measured (e.g., soil type, slope, forest type, climate).

Whenever possible we tried to view the hypothesis evaluations in light of the current interim guidelines by asking these questions:

1. Do the interim interior forestry guidelines cover the effect(s) described by the hypothesis (e.g., increased sedimentation, changed flow regime)?

2. Do guidelines or procedures developed elsewhere apply to this effect?

3. Would the effect be significant without any guidelines?

Research Design Workshop

This workshop focused on effects of timber harvesting in the Stuart-Takla watershed on fisheries resources. Specifically, the workshop was designed to meet these objectives:

1. Adapt existing conceptual models to the Stuart-Takla watershed, focusing on water, sediment, and fish, and covering the entire area from the uplands through the riparian-zone and floodplain, and into the channel.

2. Using the conceptual model(s) as a guide, catalogue important information needs and key data gaps.

3. Identify scientific questions and impact hypotheses to be tested in this program.
4. Develop or refine experimental approaches to, and tests for, the scientific questions and impact hypotheses, building—wherever possible—on existing research projects and study designs.

5. Discuss options for the experimental timber harvesting plan.

Much of the time during the workshop, participants were operating in small subgroups. There were three sub-groups, representing three portions of the natural system: (i) upland; (ii) riparian-zone, floodplain, channel; and (iii) aquatic biota. The charge to participants was to address objectives one through four, above. Subgroups were also asked to begin considering issues associated with objective 5. The final plenary session was devoted to overall discussions and focused on immediate needs and identifying an optimal timber harvesting plan, from a scientific, experimental-design perspective.

![Diagram](image)

**Figure 4:** Simplified model, illustrating the contributions of natural and forest-harvesting processes to inputs of sediment, large organic debris, and water to nearby streams.
UPLAND SUBGROUP

Conceptual Model

Members of this subgroup focused their attention on the relationship between forestry-related activities in the upslope area of the Stuart-Takla watershed and potential effects on the inputs and timing of sediments, large organic debris, and water to the stream channel. A simplified conceptual model, shown in Fig. 4, was developed to help clarify the relative contributions of natural and forestry-related processes.

Desired Data and Information

Adequately addressing the issues and hypotheses pertaining to upland processes will require a substantial amount and diversity of information and data. Subgroup participants began by identifying a list of such information and data (Table 2).

Table 2: Information and data required to address the issues and hypotheses pertaining to upland processes.

<table>
<thead>
<tr>
<th>Component</th>
<th>Needed Data or Information</th>
</tr>
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<tbody>
<tr>
<td>Climate</td>
<td>• precipitation</td>
</tr>
<tr>
<td></td>
<td>• solar radiation</td>
</tr>
<tr>
<td></td>
<td>• air temperature</td>
</tr>
<tr>
<td></td>
<td>• relative humidity</td>
</tr>
<tr>
<td></td>
<td>• windspeed and direction</td>
</tr>
<tr>
<td></td>
<td>• soil temperature</td>
</tr>
<tr>
<td>Water</td>
<td>• water flow</td>
</tr>
<tr>
<td></td>
<td>• water quality</td>
</tr>
<tr>
<td></td>
<td>• changes in water delivery at site level</td>
</tr>
<tr>
<td></td>
<td>• soil water storage</td>
</tr>
<tr>
<td></td>
<td>• groundwater storage</td>
</tr>
<tr>
<td></td>
<td>• groundwater flow</td>
</tr>
</tbody>
</table>
Sediment
- sediment source map
- sediment source classification
- sediment production by source, soil class, season, particle size
- sediment delivery

LOD
- potential for large organic debris production
- rate of production
- threshold age class

Note that all of the items on this list are desirable, but not all are practical for inclusion in a field research study, such as proposed for the Stuart-Takla. For instance, the participants had difficulty in even defining soil water and groundwater at an operational level, and were unsure how such data could be economically collected on a large-scale watershed basis.

Research Hypotheses

The subgroup then identified seven null hypotheses that need to be addressed in the upland area:

1. Forestry activities have no impact on amount and quality of sediment production;

2. Forestry activities have no impact on sediment delivery to stream channels;

3. Climate conditions during the study periods are not significantly different from the long-term means (and variance);

4. Forestry activities have no impact on site microclimate;

5. Streamside (riparian-floodplain edge) harvesting has no impact on LOD supply;

6. Forestry activities have no impact on soil water chemistry; and
7. Forestry activities have no impact on groundwater flow, temperature, and chemistry.

Details for each of the first five hypotheses are provided below. The group could not agree on particulars for the last two hypotheses. As well, some of the more important linkages between these five hypotheses are listed in Section 3.3.6.

_Upland hypothesis one_

This null hypothesis states that forestry activities will have no impact on either the amount or the textural composition of sediment production. It is related to two key issues: 1) impacts of altered suspended sediment loads and sedimentation on fish and spawning beds; and 2) impacts of mass wasting on fish and stream structure.

There are three types of actions that pertain to this hypothesis:

1. *Road building, maintenance, use, and de-activation*: this includes mainlines, branches, spurs, and winter roads. As well, repeated entries must be considered;

2. *Harvesting*: Relevant factors are the choice of: a) silviculture system (e.g., clear-cut, partial cut, or partial retention); b) season; c) harvesting method (e.g., cable, or ground (machinery type)) and rehabilitation; and d) choice of layout design (e.g., designated skid trails; block size, shape, location; slope; proximity to streams; and machine-free zone (for small and/or ephemeral streams); and

3. *Silviculture*: The main factors here are the choice of: a) methods for site preparation (e.g., mechanical, fire, or none); b) species to plant; and c) methods for plantation maintenance (e.g., mechanical, animal control, and stand tending).

The main factors that influence the degree of impact are listed below. Each of these items is a potential indicator that should be considered for inclusion in the upslope monitoring program.
1. **Compliance:** a) with road and trail building and maintenance standards (e.g., Forest Practices Code), and b) with harvesting standards (e.g., soil conservation guidelines, Forest Practices Code);

2. **Roads:** a) location, length, width, and type of road; type of road surface; b) cuts, fills, sidecasts, end-hauling; slope, steepness; c) removal of surface vegetation and/or forest floor cover; d) soil exposure level, surface drainage, loss of soil; e) level of road use, including repeated entries; f) revegetation rate; g) intensity of rainfall/rate of snowmelt, and frost action; h) interception of soil and groundwater floor; and i) identify sediment sources, production, and delivery.

3. **Harvesting:** a) soil disturbance estimates; b) location and size of harvest unit; c) area in roads and trails d) debris distribution (e.g., fuel loading); e) low-flow regimes and high-flow regimes (e.g., amount and timing); f) removal of surface vegetation and/or forest floor cover; g) soil exposure level, surface drainage, and loss of soil; h) revegetation rate; i) intensity of rainfall/rate of snowmelt, and frost action; j) interception of soil and groundwater floor; and k) identify sediment sources, production, and delivery.

4. **Silviculture:** a) success of natural regeneration of plant communities; b) rate of growth of arborescent vegetation; c) soil disturbance estimates; d) success of treatment(s) in minimizing sediment production; e) sediment sources, production, and delivery; f) road use resulting from repeated entries; g) removal of surface vegetation and/or forest floor cover; h) soil exposure level, surface drainage, and loss of soil; i) revegetation rate; j) intensity of rainfall/rate of snowmelt, and frost action; k) interception of soil and groundwater floor; l) identify sediment sources, production, and delivery; m) soil disturbance estimates; n) location and size of harvest unit; o) area in roads and trails; p) debris distribution (e.g., fuel loading); and q) low-flow regimes and high-flow regimes (e.g., amount and timing).
Upland hypothesis two

This null hypothesis states that forestry activities will have no impact on sediment delivery to stream channels. Like the first hypothesis, this one also addresses issues pertaining to: 1) impacts of altered suspended sediment loads and sedimentation on fish and spawning beds; and 2) impacts of mass wasting on fish and stream structure.

In addition to the actions listed above (road building, maintenance, use and de-activation; harvesting; silviculture), there are four more actions to consider here. These are: 1) number and location of culverts; 2) settling ponds; 3) vegetation of ditches; 4) different types of maintenance (e.g., ditch clearing); and 5) distance of disturbance to perennially flowing streams.

Likewise, many of the indicators listed in the previous section also apply to this hypothesis. But there are also five additions: 1) vegetation and revegetation techniques; 2) ditch bedload; 3) evaluation of maintenance of natural drainage patterns (creation of more erosion); 4) gradient of delivery pathway; 5) sedimentation; and 6) ditch erodibility.

Upland hypothesis three

This null hypothesis states that the climate conditions during the study are not significantly different from the long-term means or variability patterns. There are no special actions to consider here, but the subgroup identified two useful indicators: 1) all climate variables; and 2) collating off-site, long-term data collected by the Atmospheric Environment Service.

Upland hypothesis four

This null hypothesis is that forestry activities have no impact on site microclimate. It deals with issues related to: 1) impacts of changes in low-flow regimes on fish and their habitat; and 2) impacts of changes in high-flow regimes on fish and their habitat.
There are two actions that are of prime importance here - the choice of silviculture: 1) system and 2) regime. The main indicators are: 1) all climate variables; 2) soil moisture dynamics; 3) groundwater dynamics; 4) water-yield dynamics (amount and timing) - low-flow regimes, high-flow regimes; and 5) soil physical properties.

_Upland hypothesis five_

This null hypothesis states that streamside (riparian-floodplain edge) harvesting has no impact on the supply of large woody (organic) debris. It also pertains to the impact of upslope-riparian harvesting on riparian-floodplain vegetation. It mainly pertains to the issue of whether or not the supply of LOD to the stream is sufficient, insufficient, or excessive. But, there are other important issues as well, such as blowdown, riparian revegetation (shading, seed supply, microclimatic changes), and even stream water temperature in deeply incised portions of the stream channel.

The main actions of interest are: 1) streamside harvesting; 2) stream clearing; 3) choice of silviculture system; 4) wildlife habitat requirements; and 5) variations in buffer widths. Investigating this hypothesis requires four indicators: 1) soil properties, terrain, and slope; 2) amount (volume) of LOD, and wind-firmness; 3) wind direction and velocity; and 4) wildlife habitat use (wildlife trees and coarse woody debris).

Experimental Approaches

In addition to using conventional monitoring and operational logging plans, the participants in the upland subgroup identified three separate experimental approaches to generating scientific data for addressing the impact hypotheses: 1) sub-basin studies; 2) synoptic surveys; and 3) demonstration watersheds.
Sub-basin studies would be ideal for studying the effects of high impact developments and alternative development methods. By varying the degree and type of perturbation, it would be possible to examine ecosystem responses in key factors such as water yield dynamics (e.g., surface flow, subsurface (soil) flow, groundwater), and water quality impacts. Sub-basin studies could also be used for limited-scale, "black box" studies of processes controlling soil water storage; soil water chemistry; and groundwater flow, temperature, and chemistry. Other uses of sub-basin studies could include investigations of unstable terrain and soils, and system responses to intensive rehabilitation. The sub-basin scale would also be suitable for studies on the removal of streamside vegetation designed to improve alluvial ecosystem management.

Synoptic surveys and inventories of nearby watersheds could be used to investigate effects of existing large-scale disturbances, such as fires and beetle-kill. As well, data relevant to some of the hypotheses could be collected in watersheds in this region where there has already been heavy logging or prescribed fires. Synoptic studies could also be used for retrospective studies. If needed, some of the nearby watersheds could become part of the monitoring network.

A third option is to establish nearby demonstration watersheds. These could be used to examine specific management practices such as prescribed burns, silviculture, and beetle control.

Relationship to Other Study Components

The subgroup saw no trouble in meeting the needs of the floodplain, riparian-zone, and channel subgroup for information and data pertaining to hydrologic inputs, LOD input, and sediment inputs.

Likewise, the upland subgroup saw no major problems in fulfilling some of the most important needs of the biota group. Key information needed by the biota group includes: 1) hydrologic inputs, especially information on timing of expected changes in water input; 2) LOD inputs; 3) sediment inputs, especially amounts and size fractions of sediments; and
4) sediment and LOD inputs for critical fish habitat (both spawning and rearing). In addition, the biota group might need information on changes in: 5) nitrogen and phosphorus levels; 6) photosynthetic light; and 7) stream water temperatures. Some activities might be needed in the upslope area to assist in providing this information, if it is indeed needed by the biology group.

Subgroup members also indicated that this proposed work must be linked to, and put in context with, other current studies and programs dealing with:

- basic ecological studies on vegetation, soils, and animals, including work on processes (succession, forest regeneration), disturbance ecology, and ecosystem resilience;

- biodiversity objectives;

- long-term ecosystem health and productivity;

- wildlife habitat studies (e.g., furbearers, small mammals, birds);

- riparian-zone/upslope linkages;

- watershed/landscape linkages at both local and regional scales;

- timber productivity studies; and

- social needs pertaining to aboriginal values and uses (e.g., vegetation, furbearers, fish).

Options for Experimental Timber Harvesting

Two options for timber harvesting were identified. First is conventional even-aged silvicultural management. This could be applied in the uplands in fire-origin stands or in
clearcuts, saving seed-trees. Alternatively, experimental silviculture practices could be tried. This might include: 1) harvesting in riparian (floodplain) areas, with upland buffers for the floodplain; 2) high-elevation sites; 3) selection systems; 4) shelterwood silvicultural practices; or 5) partial retention. The selection silvicultural system maintains a continuous, uneven-aged forest cover by harvesting a limited number of trees, of various sizes and ages, over time. The seed-tree silvicultural system leaves selected trees standing in a cut block to provide a natural seed source for regeneration. With the shelterwood silviculture system, mature trees are removed in a series of cuts, designed to establish a new, even-aged stand under the shelter of the remaining trees. The choice of which silvicultural system to use here should take into account links to wildlife habitat research and management needs. One pressing problem is to develop a prescription for the beetle problem. Participants also indicated that, ideally, there would be no cutting for at least three years to allow upland researchers to get their programs established and to collect substantive baseline data.

Short-Term Action Plan

Participants in this subgroup recommended the following items as priority work to be done before harvesting begins:

- develop management policies (e.g., IFFWS, FPC, herbicides);

- complete management, research, and demonstration plans;

- establish monitoring networks for climate, water, and sediment;

- identify candidate sub-basins;

- ecosystem mapping;
• identify experimental harvesting opportunities and options;

• identify nearby watersheds;

• identify socially sensitive areas within the Stuart-Takla watersheds (e.g., traditional use, heritage use); and

• fully establish partnership involvement of all interested parties, including aboriginal groups.

FLOODPLAIN, RIPARIAN-ZONE, AND CHANNEL SUBGROUP

Conceptual Model

The subgroup considered the conceptual models presented in the plenary session and decided that neither one helped them to conceptualize the area/topics that the group was charged with, and that these models would not, therefore, be useful tools to guide subsequent subgroup discussions. Instead, they identified the model depicted in Fig. 5 as a more useful way to conceptualize the floodplain, riparian-zone and channel issues that they were charged with considering.

Zone A encompasses the high-elevation source channels. These are confined channels characterized by a pool-step morphology. Mass wasting (landslides) is the primary input mechanism for sediments and large organic debris. Zone B is a lower elevation transport/deposition zone. The channel has a pool-riffle-bar morphology, and flows within a riparian ecosystem. Stream erosion is the primary mechanism for sediment input in zone B. Zone C is a deposition zone; the channel is relatively unconfined and has a sand-pool-riffle
morphology. In the Stuart-Takla watersheds, there are no fish in zone A, zone B is primarily trout habitat, and zone C is primarily sockeye habitat.

Figure 5: Generic diagram of a stream, depicting three distinct zones based on relative elevation, distance from the source, and channel morphology characteristics. A = high-elevation source channels; B = lower elevation transport and deposition zone; and C = deposition zone.

Desired Data and Information

Each member of the subgroup was asked to identify the three research questions that they thought would contribute the most significant new understanding to how floodplain, riparian-zone, and channel processes are affected by forest management practices (recognizing that the ultimate goal is to identify how these processes will collectively affect fish). The following list emerged:

1. How does channel morphology change in response to changes in the flow regime?
2. What are the interactions among fines, gravel, and aquatic biota, and how do these interactions change in response to logging?
3. What width of leave-strip is required to maintain riparian-zone integrity?

4. What are the in-channel and riparian-zone debris budgets?

5. What effect does logging have on stream channel temperature (especially during the winter)?

6. What is the potential for sediment and debris torrents from zone A to zone B, and what torrents actually occur?

7. What is the sediment budget of coarse material in the channel?

8. How long does it take for the channel to revert to its original state (i.e. what is the temporal horizon of channel change)?

9. How does sediment and debris interact?

10. What impacts do beavers have on channel morphology?

11. What impacts do cutting and road building have on the stability of lacustrine deposits, and how does this affect the amount of fines entering the stream?

12. What is the role of soil-water movement in both natural and clearcut areas?

13. How do sediment delivery mechanisms differ among alternate harvesting methods that decrease road density and road number?

14. What effect does logging have on snow accumulation and snowmelt?
15. What are the channel and watershed characteristics of the Stuart-Takla areas where research is being conducted?

Question 15 is important if results of this study are to be extrapolated to other watersheds in the interior, and is not specific to this subgroup. Questions 11 -14 were recognized as being the domain of the upland subgroup, or the domain of both the upland and floodplain, riparian-zone, and channel subgroups, and were therefore not considered further in discussions by this subgroup. Of the remaining questions, the subgroup had time to identify hypotheses for only questions 1 through 5. Research questions 1 through 4 were selected because they were considered to be the most important of the 15 listed questions, while research question 5 was chosen for examination because hypotheses could be identified within the remaining time.

Research Hypotheses

The subgroup identified sixteen research hypotheses for the first five questions; these are presented below.

Q.1. Changes in channel morphology

When identifying research hypotheses for the first question, the subgroup members believed that changes in sediment and debris regimes had more of an impact on channel morphology than on changes in flow regime. The group also recognized that interactions among flow, sediment, and debris regimes were important in determining channel morphology. The focus of the research hypotheses were expanded accordingly:

A. A change in flow regime will lead to a change in channel morphology. This change in morphology will differ among zones A, B and C. Zone A channels will change from a step morphology to a chute morphology. The pool-riffle-bar characteristics of zone B channels will change. The transition area between zones B and C will shift
downstream (i.e. deposition will occur further downstream). Greater deposition will occur in zone C, because greater amounts of material are available to be transported.

B. A change in sediment regime will lead to a change in channel morphology. (The details of this hypothesis are identical to those for changes in flow regime.)

C. A change in debris regime will lead to a change in channel morphology. This change in morphology will differ among zones A, B and C. Zone A channels will change from a step-pool morphology to a channel controlled by debris-jams. The pool-riffle-bar characteristics of zone B channels will change. The debris characteristics (volume, size, orientation) will change in both zones B and C.

D. Sediment and debris are more important than flow in changing channel morphology. There are four hypotheses that pertain to this research question: i) Debris-induced changes last for a longer period of time than sediment-induced changes; ii) As sediment and debris increase, there will be a higher riffle-pool ratio; iii) Zone B channels will widen, riffles will extend, and pools will fill; and iv) In zone C the depth of the water will be reduced, pools will fill, sinuosity will decrease, and the channel will straighten.

Q.2. Interactions among fines, gravel, and biota

E. Logging will lead to an increase in the percentage of fines, causing a decrease in incubation success of salmon eggs.

F. This increase in fines will swamp the ability of salmon to clean incubating gravels.

G. Logging will increase debris which will lead to increased storage of fine (i.e. suspended) or coarse sediments.
H. Small debris leads to decreased stability of debris-jams and more frequent pulses of sediment transport. In other words, debris-jams made up of small debris are more likely to break and release sediment than are debris-jams comprised of larger debris. (A related hypothesis, added by a reviewer, is that LOD from deciduous sources is not as stable as that from coniferous sources.)

Q.3. & Q.4. Riparian-zone integrity, and in-channel and riparian-zone debris budgets

The subgroup considered the following hypotheses to be applicable to both research questions 3 and 4, as they are related:

I. Narrow leave-strips (less than one tree-height) increase the input of large organic debris to the channel from the riparian-zone, and decrease channel stability.

J. Large leave-strips (wider than three times the mean tree height) lead to smaller effective leave-strips, in response to beetle kills. (Implicit in this is the hypothesis that large leave-strips are more susceptible to beetle infestations than smaller leave-strips.)

K. Buffer strips filter sediment delivery to the stream.

L. Riparian sources of large organic debris are critical to channel stability.

M. In-channel large organic debris is critical to riparian-zone development and off-channel development.

Q.5. Effects on stream temperature

N. A decrease in riparian cover will increase the amount of sunlight reaching the stream and therefore increase water temperature.
O. Timber harvest will increase stream temperature throughout the year. (There is some uncertainty as to whether an increase in winter water temperature would affect fish.)

P. Timber harvest will increase water temperature in August, which will decrease spawning success and increase incubation rate (which in turn will lead to early fry emergence and altered survival).

Short-Term Action Plan

The subgroup did not have time to discuss experimental approaches for these research hypotheses (although the suggestion was made during the discussion of hypothesis 10 that it would be nice to leave a stand of riparian timber alone after a beetle-kill, to observe the riparian-zone and in-channel effects, instead of the usual practice of salvage logging). However, in order to facilitate the next steps of the research project, the group identified a list of activities that should begin as soon as possible, based on the subgroup discussions to that point in the workshop. The suggestions are listed in the order in which they were identified in the subgroup, and does not imply order of priority:

- Sub-basin work needs to be done, particularly sampling of sediment and debris. This raises the question of access to these basins: the method whereby researchers gain access to sample pre-disturbance conditions should not in itself constitute a disturbance.

- Convene a sub-group or committee to re-examine past and current sediment sampling approaches and strategies, to ensure that the sampling done as part of this project is appropriate.

- Determine where fine sediments are deposited in zone C (including Middle River).
• Conduct sediment/channel morphology studies, install scour monitors in all three zones, and obtain an inventory of zone A (perhaps through low level aerial photographs).

• Explore opportunities to tailor computer simulation models (such as the FFIP model or the Harris Creek model) for use in interior watersheds.

• Investigate the timing of bedload movement.

• Conduct an inventory of both in-channel and out-of-channel sediment sources.

• Determine the particle size distribution of suspended sediments.

Clearly, some of these tasks will take longer than others, and not all could be completed before the scheduled fall timber harvest.

Looking Outward Matrix

Table 3 lists the information that the biota group first said they would want from our group. A check mark (✓) indicates information that can already be provided, to some extent, with current data (although the data availability in terms of spatial or temporal scope may be limited). An asterisk (*) indicates information that could be provided from the Short Term Action Plan.

Leaf litter inputs and ice are two topics absent from the short term action plan but that were identified as important research hypotheses by the biota subgroup.

The three types of information required by the upland subgroup from the floodplain, riparian-zone, and channel subgroup (bank stability; magnitude of flow change that will alter
channel morphology; and large-organic-debris requirements for channel stability) could all be satisfied through research conducted to test the five main questions described above. The group noted, however, that the second information requirement was somewhat misguided, since changes in sediment and debris regimes are likely to be more important than flow changes in affecting channel morphology.

**Table 3:** Looking outward matrix excerpt: information the biota subgroup said they wanted from the floodplain, riparian-zone, and channel subgroup, and the availability of that information.

<table>
<thead>
<tr>
<th>Information the Biota group wants from the Floodplain, Riparian-Zone, and Channel group</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaf litter inputs</td>
</tr>
<tr>
<td>✓ amount and timing of water inputs (surface water and groundwater)</td>
</tr>
<tr>
<td>* sources/routings of fine sediments</td>
</tr>
<tr>
<td>✓ mass of sediments by size fraction</td>
</tr>
<tr>
<td>✓ sediment concentration, duration, timing and deposition rates</td>
</tr>
<tr>
<td>✓ spawning gravel quality</td>
</tr>
<tr>
<td>* deposition sites</td>
</tr>
<tr>
<td>* frequency of bed mobilization</td>
</tr>
<tr>
<td>* depth of bed mobilization</td>
</tr>
<tr>
<td>✓ large organic debris</td>
</tr>
<tr>
<td>✓ relative amounts of riffles/pools</td>
</tr>
<tr>
<td>✓ stream temperature; photosynthetic light</td>
</tr>
<tr>
<td>anchor ice; frazil ice</td>
</tr>
<tr>
<td>✓ time scale of channel morphology change</td>
</tr>
</tbody>
</table>

✓ - information that is currently available to some degree, although the spatial and temporal scope of much of it is limited

* - information that the Short Term Action Plan could provide
BIOTA SUBGROUP

As indicated by a listing of current scientific activities in the Stuart-Takla watershed (see Appendix B), a considerable amount of research and investigation has already been devoted to the aquatic ecosystem, and to salmonid species in particular. This is not to suggest that all of the good research questions have already been answered. To the contrary: the depth and quality of available data and information simply improves our ability to make reasonable predictions regarding how parts of the ecosystem will respond to perturbations resulting from forest harvesting.

In the past, research in these systems by the federal Department of Fisheries and Oceans focused mainly on anadromous sockeye salmon. Now, research by the provincial government (Ministry of Forests and Ministry of Environment, Lands, and Parks) is being directed not only toward sockeye and kokanee salmon, but also toward other fish species, such as trout and char. When constructing the impact hypothesis diagram, the participants included all mechanisms potentially affecting any fish species.

Because of the complexity of the aquatic ecosystem, and the myriad linkages with nearby terrestrial ecosystems, an impact-hypothesis diagram is useful for helping to identify pathways by which impacts may be propagated through the system. Such a diagram is also helpful for evaluating available data and information, thereby assisting with the process of isolating key unknowns and high-priority research topics.

Conceptual Model

Using the draft conceptual models developed prior to the workshop as prototypes (c.f. Fig. 2, 3), the biota subgroup generated an impact hypothesis diagram capturing physical, chemical, and biological pathways by which forest harvesting and associated activities (e.g., road building)
may affect fish in all life stages from egg to spawning adult (Fig. 6). This diagram contains 46 hypothesized linkages, not all of which are expected to be valid or equally important. However, all may be of some significance in controlling fish production in the streams of the Stuart-Takla watershed.

Some of the impact hypotheses are already well known and have been extensively studied elsewhere. These include, for example, hypotheses dealing with physical changes related to discharge, water temperature, and suspended sediments. For these hypotheses, proven experimental designs and data collection methods are available. In contrast, there are other impact hypotheses that are not only more speculative, but considerably more difficult to study. One example is the hypothesis dealing with nutrients and dissolved organic matter stimulating populations of bacteria and fungi which then attack incubating fish eggs in the gravel, thereby reducing incubation success (linkages 2, 26, 27, 28).

The impact hypothesis diagram also lists 18 major factors directly affecting fish production (linkages 1 - 18). Studies for many of these are already underway, but the subgroup participants identified five that are not well known and that probably require attention (linkages 9, 15, 11, 16, 17).

Desired Data and Information

The data and information needs of the biota group are summarized in this listing:

<table>
<thead>
<tr>
<th>physical</th>
<th>channel morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>woody debris</td>
<td></td>
</tr>
<tr>
<td>bedload</td>
<td></td>
</tr>
<tr>
<td>suspended sediments</td>
<td></td>
</tr>
<tr>
<td>fine organic matter</td>
<td></td>
</tr>
<tr>
<td>spawning gravel</td>
<td></td>
</tr>
<tr>
<td>discharge (annual water output)</td>
<td></td>
</tr>
<tr>
<td>water temperature</td>
<td></td>
</tr>
<tr>
<td>water velocity</td>
<td></td>
</tr>
</tbody>
</table>
Research Hypotheses and Experimental Approaches

Biota subgroup participants selected six main suites of hypotheses to discuss in detail. These were chosen in part because they are less well known than many of the other hypotheses. The hypotheses selected for discussion involved insects, ice, water temperature, and predation.

An overarching challenge, associated with many of the following hypotheses, is the accurate measurement of "incubation success" and "rearing success". The numbers of individuals that survive to the end of a particular life stage is but one measurement - others include size and condition. These other measurements may be particularly important in detecting sub-lethal effects of land-use impacts. Thus, while the following paragraphs are biased toward coarse-scale
Figure 6: Impact hypothesis diagram for fish. This illustrates potential impacts of changes in water discharge, woody debris, bedload, suspended sediment, fine organic matter, and nutrients on fish egg deposition, incubation success, rearing success, and size and numbers of out-migrating fish. The legend is as follows: circles = high priority; ovals = medium priority; numbered squares = relationship known, but relevant data may be available from other research; dotted ovals = questionable hypothesis; Roman numerals = information and data requested from other subgroups.
measurements of impact (i.e. emergence and out-migration numbers), such measurements may prove inadequate for describing all of the important effects that changes in land cover and use have on fish populations and communities.

Insects and rearing success

Hypothesis: Per capita fish growth rate is a function of food abundance. Thus, changes in insect community composition and abundance are of potential significance, especially if there is a shift toward more chironomids. This hypothesis pertains to linkages 25, 44, 24, 15, 23, 45, 43, covering nutrients, periphyton, suspended sediments, and water temperature.

Indicators: abundance and composition of benthic macroinvertebrates, drift, and terrestrial macroinvertebrates

Methods: colonization baskets, fish stomach samples, insect emergence, drift, and benthos samples, adhesive traps for aerial insects

Strategies: sample at stable flow period (July?) - two options: (a) BACI (Before/After - Control Impact) experimental design: 1 control, 2 treatments, with the treatments at either end of a gradient from "best forest harvesting practices" to "minimal forest harvesting practices"; (b) synoptic: logged versus unlogged

Challenges: low statistical power; increase by increasing the number of reference sites
Ice, incubation, and rearing success

Hypothesis: (Linkage 9) low winter water temperatures may lead to ice scouring and freezing of the eggs, but temperature affects developmental stage, which affects mobility, which may lead to avoidance

Hypothesis: (Linkage 16) ice scouring may lead to ice dams, which may result in habitat disruption and stranding of juveniles

Indicators: egg-to-fry mortality (ice affects only one factor)

Methods: (a) glass vials in gravel [if broken indicates freezing took place]; (b) thermistor - measure number of days with temperature ≤ X °C in the gravel

Strategies: place vials or thermistor with experimental apparatus for incubating eggs

Challenges: (a) associate changes in incubation/rearing success with anchor or frazil ice; (b) ice conditions may not occur every year

Water temperature and rearing success

Hypothesis: There is some upper limit above which increased water temperatures lead to reduced growth (c.f. Fig. 7)

Indicators: juvenile fish numbers and growth (size), and water temperature

Methods: water-temperature loggers, mark-recapture
**Strategies:**
measure water temperature throughout the study system: Gluskie, O'Ne-eil, Forfar (not just in the lower reaches)

**Challenges:**
(a) relate changes in water temperature to particular factor(s) associated with forest management; (b) link changes in water temperature to changes in rearing success

**Figure 7:**
Hypothetical relationship between water temperature and juvenile fish growth, showing upper limit and zone of exclusion.

**Predation**

**Hypothesis:**
Predation by fish, birds, and mammals may affect fish rearing success (Linkage 11). There is a positive feedback, such that with an increase in juvenile fish numbers, there is a corresponding increase in predator numbers. Some predator species may be "riparian obligates", and especially affected by stream-side harvesting practices. Key to this hypothesis are issues concerning
the timing of the period when the juveniles are most exposed to predation and their degree of vulnerability.

**Indicators:**
predator numbers, sizes, and species; predator diets; relationships between these factors

**Methods:**
catch/unit effort of the predators; gastric evacuation rates of predators; diet analysis

**Strategies:**
BACI experimental design; seine or gill net samples from off the mouth of the spawning/rearing creeks

**Challenges:**
for observers to (a) be in the right place at the right time, (b) have sufficient observational "power" to adequately record the event, and (c) choose methods that minimize bias (i.e. adequate sampling of all species and sizes)

**Overall rearing success**

**Hypothesis:**
There will be a change in fish numbers and/or size at time of out-migration after a land-use impact.

**Indicators:**
(a) local density (standing crop) and (b) size-at-age for sockeye, trout, char, and possibly kokanee

**Methods:**
(a) mark-recapture; (b) fences; (c) population abundance

**Strategies:**
BACI, either: (a) site sampling; or (b) monitoring at the mouth
Challenges: statistical power for trout and char; perhaps better to focus on one system (e.g., O’Ne-eil); note: need to detect a change of 10-15% or greater to have implications for amending the forestry guidelines. This value, in turn, has implications for data quality objectives.

Fish input/output

Hypothesis: Forest harvest will reduce the production of fish in the rearing streams. Trout, char, and sockeye all use the creeks in the Stuart-Takla drainage at some time each year, at some period in their lives.

Indicators: stock-recruitment relationship for trout, char, and sockeye: (a) number of adults in; (b) number of fry out

Methods: (a) mark-recapture; (b) fences; (c) radio-tags

Strategies: (a) sample at the mouth of each creek; (b) lake hydroacoustics

Challenges: (a) if "outside" mortality is high, then minor changes within the basin (due to the perturbation) may be relatively unimportant to the population; (b) timing may be different for each species

Other issues

Participants also raised several other points that are not well addressed in the hypotheses and activities described above. For example, there was concern that a focus on sockeye, trout, char, and Kokanee would draw attention away from issues related to changes in
fish diversity and community composition. To address this concern, effort would need to be devoted to other fish species, such as cyprinids in the Middle River and Takla Lake. There was also interest in genetic changes in the fish populations, associated with perturbations. Someone raised a question pertaining to interpretation of the data *vis a vis* "healthy" or "sustainable" fish communities. Finally, the point was made that our hypotheses assumed that the perturbation would be due to forest harvesting, but that there are other perturbations that could affect the system, such as pests and fire.

Relationship to Other Study Components

To investigate and understand changes to the biota, investigators will need information concerning eleven important factors, namely channel morphology, woody debris, bedload, suspended sediments, nutrients (N, P), dissolved organic carbon, fine organic matter, spawning gravel, discharge, water temperature, and water velocity. These data and information will need to come from work done in the upslope and floodplain, riparian, and channel areas of the watershed.

Options for Experimental Timber Harvesting

There was not much time in the subgroup to discuss cutting plans, but the participants did discuss three points in brief. First, there was agreement that any logging operations in the fall of 1994 should be restricted to one sub-basin (e.g., Gluskie). Second, there should be immediate, prelogging access to two key sites. This requires creating some sort of trail for light vehicles. Finally, there was discussion of the idea of using a variable-width leave-strip with increasing porousness and feathering, to permit investigations of wind-firmness and blow-down.

Short-Term Action Plan
The biota subgroup identified seven high priority items that should be initiated as soon as possible, ideally before harvesting begins. Note that these are new initiatives, above and beyond those that are already underway (see Appendix B).

1. *Insect/Periphyton/Nutrients:* main activities here are (a) investigate and select appropriate insect sampling methods, and (b) make arrangements for someone to take responsibility for nutrients and water chemistry;

2. *"Sediment Capping":* the issue here is fry "entombment"; need to devise a means to monitor for occurrence, and to identify the responsible sediment fraction (if any);

3. *Sediment Mapping:* should include both summer and winter habitat;

4. *Additional Reference Sites:* to increase statistical power, need additional reference sites in suitable locations; check out Frypan, Forcythe, Flemming and other nearby creeks to locate candidates;

5. *Predators:* need to do a survey to identify potential predator species; use literature values to estimate potential importance;

6. *Temperature:* carry out a literature review to determine the approximate relationship between water temperature and growth [expressed by both egg development, and alevin migration]; establish temperature monitoring stations in the upper parts of the watersheds under investigation; begin monitoring sub-gravel temperatures; and

7. *Out-migration:* during the period March through September, measure fish migrations from Gluskie, Forfar, and O’Ne-eil Creeks; this may require modifications to the fence, or use of a Fyke net or rotary sampler.
DISCUSSION AND SUMMARY

On the final day of the workshop, all participants assembled for a plenary session. Each subgroup presented the results of their deliberations. One important point that surfaced was that the research needs to be designed around a set of data quality objectives (DQO). The principle determining the DQO is that the research program needs to be capable of detecting a change of 10 - 15% or greater in fish populations. Such a change would have important implications for amending the forestry guidelines.

Participants also spent considerable time discussing an optimal experimental timber harvesting design. The option of delaying cutting for a few more years is favoured by some parties (e.g., B.C. Ministry of Forests), but would create difficulties for others, especially those funded under the Canada Green Plan initiative (e.g., Department of Fisheries and Oceans). However, through continued discussion, the participants created a multi-component plan for forest harvesting, illustrated in Fig. 8.

There are four main elements to the proposed plan:

1. establish immediate access to the Gluskie and O’Ne-eil sites shown in Fig. 8. Access should be by either trail or by helicopter. Creating a forestry road at this time would compromise some of the proposed research;

2. install a network of stations for monitoring climate, hydrology, and sediment transport. The network should include stations in all three basins (Gluskie, O’Ne-eil, Forfar) and at three levels in each basin: low, medium, and high-elevation;

3. if necessary, harvest the merchantable timber at the mouth of Gluskie Creek in the fall of 1994. This might generate useful experimental data for those initiatives that have been underway for several years, while providing other researchers with an
Figure 8: Map showing Gluskie, Forfar, and O’Ne-eil Creeks and potential areas for research and possible harvesting.
opportunity to test their methods and approaches. However, it was acknowledged that forest and terrain concerns, along with new requirements under the provincial Forest Practices Code, may lead to a harvesting design that limits floodplain and streamside land-use impacts in this particular area to levels below that which can be effectively measured; and

4. leave Forfar as a control system (no stands of merchantable timber exist there).
REFERENCES CITED


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APPENDIX B: CURRENT RESEARCH ACTIVITIES

The following is a listing of many of the data collection and experimental activities in the Stuart-Takla region that are currently being undertaken by staff from government agencies and universities. Note that this list is neither exhaustive nor detailed. For more information the reader is encouraged to contact the pertinent agency listed with each project.

Department of Fisheries and Oceans, Operations Branch, Fraser River Management Division, Richmond

1. Sockeye spawner enumeration and return time estimates of the early Stuart run, have been made annually from fence counts and dead pitch activities in each of the experimental watersheds (Gluskie, Forfar and Kynch). Data collection occurs between mid-July and late August. Estimates have been collected since 1938.

2. Fecundity estimates, length measurements and an assessment of fish condition are taken in conjunction with the fence counts.

3. Fry abundance and out-migration timing estimates are made with inclined plane traps set at the mouths of all experimental streams. This information in conjunction with fecundity estimates will enable the calculation of egg-to-fry survival estimates. Information is available since 1989. Collections are made in the evenings (2100-0100) from early April to early June.

4. Escapement estimates of the late run of Stuart sockeye are made from beach seine collections in the Middle River. These fish spawn at the mouths of Middle River tributaries from early September to October.
Department of Fisheries and Oceans, Operations Branch, Habitat Division, Vancouver

1. Equipment has been designed to measure erosion rates and sediment production from road right-of-way construction. Preliminary data were collected during the summer of 1993. This project requires point source sediment samples from each stream in order to achieve maximum benefit.

2. The impact of clearcutting on snow accumulation is being measured with the aid of automatic sampling equipment located between Gluskie and Forfar watersheds. This equipment was installed in the fall of 1993.

3. Snow course transects located on the valley floor of each stream were taken in March of 1992 and 1993. Snow depth and volume, and water equivalency estimates were made. The impact of snow-pack on stream temperatures will be examined.

4. Groundwater levels and pressure gradients are being measured with water-wells and piezometers located on transects on the valley floor of each watershed. Preliminary measurements have been taken since the spring of 1993. Transects are placed to coincide with stream sections where gravel quality and incubation habitat information is being collected.

Department of Fisheries and Oceans, Science Branch, Salmon Habitat Division, Vancouver and Nanaimo

1. Data loggers have been located in all streams since 1991 to collect stream heights, water and inter-gravel temperatures, and turbidity levels. In conjunction with water velocity ratings on each stream and year-round suspended sediment collections, we have rough estimates of water and sediment output from each system.
2. A weather station located at the Fisheries Camp, has provided us with air temperatures, rainfall and radiation measurements since the spring of 1991.

3. Streambed gravel size composition estimates have been made from freeze core samples taken from stream sections located in the lower 1 - 2 kms of each stream. Sampling has occurred during each fall since 1991.

4. Freeze core samples also provide us with redd depth information.

5. Since 1992, three times a year (April, July, September), oxygen, permeability, and temperature measurements have been taken from incubation habitats in each stream. Sample sites are all located in the lower 2 km of each stream.

6. Drift insect composition and abundance has been sampled at the mouth of each stream since 1991 with Cushing samplers. Replicated samples are taken at least twice each month from spring thaw to October. Samples were also taken in December in 1993. Concurrent water velocity measurements are also taken to calculate filtered volume.

7. Egg samples from reds in upper and lower spawning sections of each stream have been taken each September since 1992. Development rate and percent survival estimates will be made.

8. Use of six off-channel sites in Forfar Creek by sockeye fry and other salmonids was monitored by traps during spring and summer of 1993. These data augment electrofishing estimates made in 1991 and 1992.

9. A fish trap located beneath the Canfor Middle River bridge has recorded upstream and downstream fish movement. The trap has been set during the spring and summer since 1992.
10. Sockeye diets have been described from samples taken from IPT's set during spring at the mouth's of each creek. Most diet information was collected in 1991 and 1992.

11. In 1993, egg capsules were set in the gravel of each stream adjacent to locations where intergravel oxygen and temperature measurements are made. Egg development rates, survival and fidelity of eggs from neighbouring streams will be examined.

12. Opportunistic collections of stomach samples from potential predatory fish have been made each summer. With additional collections and improvements in experimental design, impacts on sockeye fry survival in Middle River can be calculated.

13. Lake productivity estimates have been made from samples taken at two locations at the southern end of Takla Lake. The degree to which fry out-migration timing coincides with lake production will be examined.

B.C. Ministry of Forests, Forest Science Section, Prince George Forest Region

1. Soil surveys and terrain mapping activities have occurred in the experimental watersheds since 1992. This work has produced an inventory of the sediment sources and terrain formations within each watershed, that are most susceptible to land use impacts.

2. A sediment monitoring strategy is being designed to quantify the production and delivery of upslope sediments to aquatic habitats. Ultimately, this research component will result in a planning tool to ensure that land use activities produce minimal sediment related impacts on water sources.
1. Channel scale surveys of the lower 3 - 4 km. of each experimental stream have been made using low level aerial photographs and ground surveys. Surveys were initiated in 1992 and will continue through the course of the experiment. Focus is on the channel morphological features that are of direct relevance to fish habitat (e.g., pools, riffles, LOD characteristics).

2. Reach scale surveys are also being conducted within three reaches in each experimental stream in conjunction with the channel scale surveys. During the summer of each year, engineering survey techniques are used to provide a detailed examination of channel morphology, channel bank characteristics and bed material location. The location and the role of LOD in channel dynamics is also being examined.

3. Estimates of spawner abundance, and the distribution of sockeye and kokanee on the entire spawning ground of each experimental stream have occurred during the period of peak spawner abundance since 1992. Estimates are made from counts of anadromous sockeye and kokanee on 1 m.-wide strips distributed at 30 m. intervals throughout the systems. Counts are compared to estimates made using other methods (fences and dead pitches). Spawner densities (quantified and ranked as high, moderate, low, etc.) are related to: microhabitat characteristics (depths, velocities, substrate composition etc.); the stream features that are responsible for channel morphology; and areas of defined habitat type determined by analyses of aerial photographs and from ground-based surveys. Spawner habitat used (distribution) and (ultimately) egg-to-fry survival will be determined relative to these physical parameters, and to processes of streambed scour and fill in cooperation with DFO. Density-dependent changes in spawner distribution, habitat use and egg survival will also be studied in cooperation with DFO by monitoring the distribution of huge samples of spawners tagged throughout the spawning season as they enter the study streams.
1. In 1993 a mid-summer survey was made of trout and char density and size in the middle elevation portions of three streams. Interior trout populations are highly dependent on small tributaries for spawning and rearing (1 - 3 year residence).

2. Stable isotope (C,N) ratios in the biota are being used in creeks with high (Forfar) and low (Bivouac) abundances of spawning sockeye to assess the dependence of secondary production in those creeks on the import of marine-derived nutrients by returning anadromous salmon.

Gottesfeld Consultants/Northwest College, Terrace, B.C.

1. Magnetically marked rocks, each uniquely numbered, have been placed in strips at two locations within the incubation habitats of Kynoch and Forfar creeks. At regular intervals throughout the year (particularly after major hydraulic events and after the sockeye have spawned) the rocks are relocated. Distance moved and burial depth are recorded to 5 cm accuracy. The relative importance of hydrologic, biologic and anthropogenic influences on bedload dynamics can be determined.

2. In conjunction with the magnetic tracer stones, bedload reservoirs have been buried on transects at the mouths of each experimental stream (including Bivouac Creek), to collect gravel as it moves downstream. Volumes weights and particle size analysis of weekly collections of the contents provide bedload movement information.

3. The flood plains associated with the experimental streams have numerous former channel segments. Mapping and measuring of these features, sequential aerial photo analysis and dating (C¹⁴) the older channels will give insight into their susceptibility to past and future
climate induced changes. This information will provide a baseline to which anthropogenic induced changes can be compared.

Department of Environment, Canadian Wildlife Service, Delta, B.C.

1. During the mid-summer of 1993 an preliminary bird survey was conducted in the riparian areas associated with the lower reaches of each experimental watershed. Avian surveys will continue in the future and will examine the use of these watersheds as avian migration corridors.
This list of a few key terms is intended to promote the use of, and clarity for, a common language pertaining to the research design and the modelling approach.

Actions

Actions are simply those activities that management can consider in their attempts to manipulate a system to meet goals and objectives. They would include such items as:

- timber area harvested within certain terrain types
- type of harvesting (cut size, clearcutting vs. partial cutting, road layout)
- method of removal (high lead, skyline, grapple yarding)
- hillslope rehabilitation
- streamside management - leave/buffer strips
- stream rehabilitation - creating/maintaining stream refugia

Indicators

Indicators are those quantities which allow one to observe and evaluate the performance of a system in response to changes in management actions. They are generally variables which have economic, political, or social importance, or at least direct relevance to environmental decisions. Examples of possible indicators include numbers of juvenile salmon, carrying capacity of fish habitat, smolt production, egg/fry survival, and numbers of returning adults.

Spatial Scale and Resolution

Any research study of a physical system is necessarily confined within some sort of spatial scale. At what scale are the individual measurements of indicators being scaled up (e.g., the whole watershed, sub-basins, terrain types, reaches)? Within the overall spatial bounds, the spatial structure may be resolved into greater detail in a number of ways. Are
measurements of different watershed components being applied on a uniform system of stratification? Can they be linked together?

**Temporal Scale and Resolution**

Bounding the research program temporally poses similar questions as were addressed for spatial bounding. Both the temporal scale (for how long should the program continue to adequately test hypotheses?) and resolution (what is the necessary frequency of measurements to track key indicators?) must be addressed. The temporal scale should be determined by the length of time required to see responses in key indicators to different timber management scenarios. The temporal resolution is determined by the rate at which important processes occur in nature. Biological indicators that integrate over the whole year are ideal, since they do not require frequent measurement.

**Subsystem Definition and Looking Outward.**

Having specified actions and indicators, as well as the spatial and temporal bounds of the system, it is necessary to divide the problem into a number of subsystems. This division is required primarily to facilitate more efficient research design development than would be possible if all participants worked together on the entire program. The Stuart-Takla FFIP program could logically be split into three subsystems (subgroups): 1) upslope processes; 2) riparian, floodplain and channel processes; and 3) fish responses.